INTERMEDIATE COURSE
OF
BOTANY

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PREFACE

This book has been written mainly for the use of students who have to read Botany for the Intermediate and Preliminary Scientific Examinations of Indian Universities, also to serve as a help-book to pursue higher studies in Botany for the B. Sc. Examination. Attempt has been made to put the subject-matter of the book in as simple a form as possible, without avoiding at the same time the technical terms which have been adequately explained. The illustrations have been carefully selected from well-known types of Indian vegetation whose vernacular names are familiar to the average student in this country. Most of the original drawings have been made, under my personal supervision from materials collected by me in the course of teaching, by Mr. Sudhir Kumar Ray, an artist of much reputation at Berhampore and great credit is due to him for the pains he has taken in preparing the sketches with the utmost scientific precision.

The scientific names of plants together with vernacular and English names, where necessary, have been given in the Appendix rather than in the body of the work to prevent confusion and horror in the minds of young learners ; and the use of vernacular names is always permitted in the University Examinations.

In dealing with the Life-history and Classification of plants, much more types and families than are prescribed for undergraduate instruction, have been introduced, as far as practicable, to illustrate the sequence of evolution from the simplest to the most complex types of plants. But all types and families which are of little importance to the beginners have been printed in small letters. In dealing with Morpho

logy, Histology and Physiology a summary or table has been added at the end of each chapter to facilitate revision of work. Questions touching important points in every chapter have been given for purposes of regular exercise.

I do not certainly claim originality in everything that I have written in this book. Much help has been obtained from various sources. Some of the chief works consulted are of the following well-known authors :—Strasburger, Coulter and Cowles, Haberlandt, De Bary, Goebel, Campbell, Scott, Darwin, Vines, Lowson, Prain, Roxbourgh, Hooker, Brandis, Rendell, Small, Reynold Green, Bose, Bower, Oliver and Mary Stopes.

It is my pleasant duty to express my sincerest thanks to my esteemed friend, Prof. Anutosh Das Gupta M. A. who has generously devoted considerable time in going through the manuscript and materially helped me with valuable suggestions during the progress of the work. My thanks are also due to Prof. Ramendra Krishna Sarkar M. A., Prof. Birendra Nath Sarkar M A., Mr. Bhujanga Bhusan Sanyal B. A. and Mr. Nirmal Chandra Goswmi M. A. who have assisted me in the publication of this work.

Inspite of all its imperfections that may be noticed by critics and others, it is hoped the book, as it stands now, will adequately meet the requirements of the undergraduate study of Botany in our colleges.

Any suggestions towards the improvement of this book from teachers and the wider circle of readers, to whom this book now goes, will be greatly appreciated.

KRISHNATH COLLEGE,
Berhampore, Bengal.
The 1st. July, 1933.

M. Roy Chowdhury.

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PART I

MORPHOLOGY

CHAPTER I

PLANT GROUPS

Botany is the science which deals with plants. **Zoology**, another science, dealing with animals is allied to Botany. Both these sciences are included under **Biology** which deals with living organisms, plants and animals.

Botany has several branches of which the following are worthy of mention :—

(1) **Morphology** treats of the forms and structures of plant members. When it is concerned with the external forms, it is called **External Morphology** commonly called Morphology. **Internal Morphology** or **Histology** treats of internal structures of plant bodies. For the closer study of the internal parts of plants the help of the microscope, a magnifying instrument, is always necessary.

(2) **Physiology** treats of all functions of the different parts of plants, external or internal. It deals with the various processes of their growth, development and multiplication. In other words, this branch is concerned with the vital activities of plants or parts of plants.

(3) **Ecology** deals with the influence of surroundings on plant life. It also considers the peculiarities or modifications observed in the structures of plants when they are affected by the environment in which they are to live.

(4) **Classification** deals with the grouping of plants according to resemblances and differences noticed in the structures of plants. When the plants are thus classified or thrown into different groups, their mutual relationships can be established.

Life in Plants

All plants are living bodies. Like animals, they try to secure their food, assimilate and grow at the cost of the substances which they manufacture. The unnecessary products of assimilation are, in most cases, somehow or other removed by them. They also multiply like animals *i. e.* they can produce new individuals similar to them. The process of breathing also noticed in the plants, consists of inhalation and exhalation which occur in the same way as in animals. The absorption of oxygen during inhalation which is a process of slow combustion of the living matter is similar to what goes on in animals. Above all, plants like animals, struggle for existence not only against animals and other plants but also against various disadvantages presented to them. Last of all, the power of movement is noticed in the lower plants and also in the various parts of higher plants.

Forms of Plants

The general idea regarding a plant is that it has at least three parts, viz. roots, stem and leaves. These three differentiated portions are in most cases present in all higher plants but they are wholly or partially absent in the lower forms of plants.

If we look at the foreign bodies commonly known as **mould** or *Chhata* grown on the surface of damp shoes or on stale moistened bread, we find that they are devoid of these parts. Again if a single drop of decomposed date juice or *tari* be examined under the microscope, it is found to contain many globular bodies having no root, stem or leaves. The long, green thread-like bodies often seen floating on the water of ponds or ditches are all plant-structures showing no differentiation of their bodies. The common **Toadstool** or *bänger chhata* though apparently so well developed is a body of the above nature. All these are plants though they have no such parts as the common higher plants usually possess. These plants are called **Thallophytes** as their bodies are undifferentiated or thallus-like. The ordinary plants which are differentiated into separate parts are called **Cormophytes**.



Fig. 1.
A small drop of date juice as seen under the microscope.



Fig. 2.
Toad-stool.

Chief Groups of Plants

There are numerous types of plants on the face of the earth. In order to avoid confusion presented by their infinite varieties of forms, it will be of great advantage to us if we have at the very outset a classification of them in a general way. Most plants bear flowers in addition to other parts. The flowers on them soon produce seeds by which those plants multiply. They are known as **Phanerogams** (*phaneros*—evident : *gamos*—marriage) whereas **Cryptogams** (*kryptos*—concealed ; *gamos*—marriage) are those which have no flowers on them though they may have roots, stems and leaves. As flowers are absent, cryptogams have no chance of seed formation. Seeds, here, are not their means of multiplication which occurs in them in a different way.

Most of the phanerogams have their flowers ultimately replaced by fruits in which the seeds lie enclosed. They are called **Angiosperms** (*angeion*—a vessel : *sperma*-seed). **Gymnosperms** (*gymnos*—naked : *sperma*—seed) are those phanerogams in which fruits are not formed : so their seeds remain naked e.g. *pines firs* etc. Most of the common plants surrounding us are examples of angiosperms. They may be Dicotyledons or **Dicots** and Monocotyledons or **Monocots**. When the seeds of angiosperms are examined closely and when they are found to contain among other parts two seed-leaves or **cotyledons**, the angiosperms are called **Dicots**, as *tentul*, *am* etc. If the seeds contain a single cotyledon the angiosperms are called **Monocots**, as *tal*, *supari*, *kalu* etc. The presence of one or two cotyledons in the seed is not the only way of differentiating dicots

and monocots. They differ in other respects which will be dealt with later on.

Cryptogams are divided into three groups :—

(1) **Thallophytes**, *e.g. common chhata*, which are totally undifferentiated.

(2) **Bryophytes**, *e.g. mosses*, which are intermediate between the other two groups *i.e.* they are not so fully differentiated as the pteridophytes nor are they completely undifferentiated as the thallophytes.

(3) **Pteridophytes**, *e.g. ferns*, which produce distinct stems, roots and leaves.

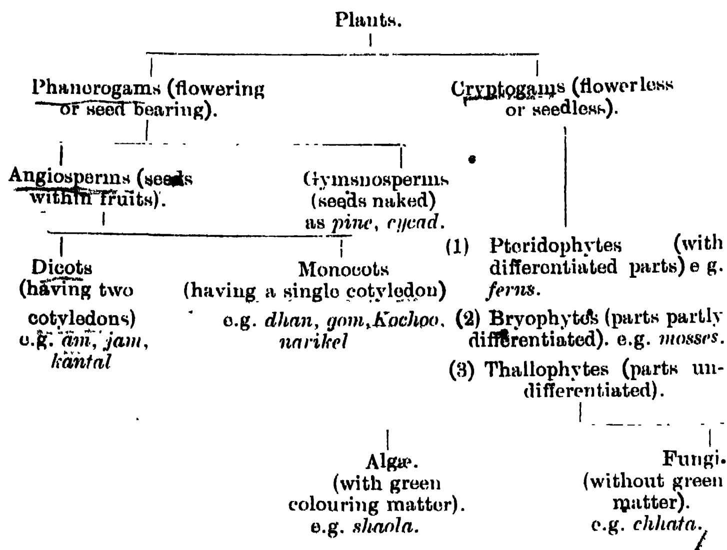


Fig. 3.

Fern plant.

Thallophytes are further classified into **Algae** and **Fungi**. Algæ possess mostly the green colouring matter which is entirely absent in the fungi.

The following table shows the above classes of plants—



Classes of plants according to the different modes of nutrition

(1) **Ordinary land plants** absorb their food materials from two sources *e. g.* soil and air. Roots are the organs by which they take in the food from the soil while the leaves suck up a kind of gaseous food from the air. The food materials absorbed from soil at last reach the leaves passing through stem and mix with those gained by the leaves. These two kinds of raw food materials when mixed up undergo several chemical changes with the help of sunlight and the green colouring matters present in the leaves. The result of all these changes is the formation of plant food on which the growth of the plant depends.

(2) **Water plants** absorb their food materials mainly from water. When they are floating, they secure their food from air also. Submerged water plants, if attached to the soil, get their food from soil in addition to water. Some of the floating plants have no connection with the soil. *Bara pana* and *khudi pana* are good examples of this type. But *padma*, *shaluk* etc, though they have floating leaves, have their stems and roots fixed to the mud. The water plants adapt their organs in such a way that they can easily absorb a large quantity of food materials found in water. The submerged plants as *pata shaola*, *jhanji*, common in most of the ponds, are usually attached to the substratum.



Fig. 4.
Lotus plant.

(3) **Epiphytes** are plants which grow on other plants but derive their food from the only source—air. They have no ordinary roots as they are not in connection with the soil. They have branched green roots hanging in the air known as **aerial roots**. These roots have on them a white layer called **velamen** which has the property of absorbing moisture from the surrounding atmosphere holding various mineral substances in solution. These roots along with the green leaves help them in the absorption of food from air.

Most **orchids** are good examples of this type of plants. *Rasua*, an orchid, is commonly found to be fixed by its roots to the upper branches of mango and other trees. It is a common

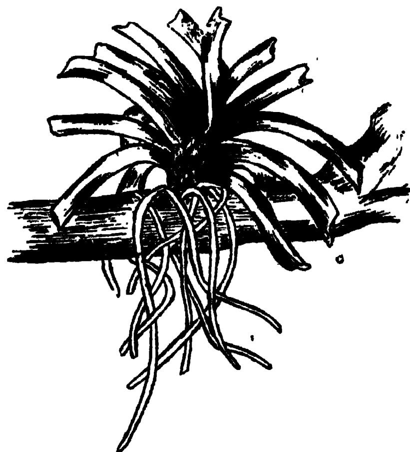


Fig. 5.
Orchid plant.

observation that a *bot* or a *peepul* tree grows on a *tal* plant and maintains no connectionwith the soil for several months till it becomes well established in the soil.

(4) **Parasites** are plants which also grow on other plants but derive their food materials therefrom wholly or partly. Thus they are **total parasites** when they take the whole of their food from the host plant thereby becoming wholly dependent upon it. They are **partial parasites** or **semi-parasites** when they are partly dependent on their host. Total parasites as *swarnalata* are usually non-green in colour, for the green colouring matters are of no use to them. They have no ordinary roots but

short stiff roots called **haustoria** which penetrate deeply into the body of the host plant in order to suck up the nourishment they require. Haustoria reach those region in the host body where th prepared food matters are in circulation. Partial parasites have in addition to haustoria green leaves and ordinary roots so that they can gather their food not only from the host but also from the soil and air like ordinary land plants. Other common examples of parasites are *akashbel*, *swetchandan*, *baramanda*, *chhoto manda* etc. *Bene-bou* is a brown-coloured small herb which grows as a total parasite on the roots of *begun*, *kapi* etc.



Fig. 6.
Swarnalata plant.

(5) **Saprophytes** are plants which grow and thrive upon decaying and rotten organic matters. They are very rare among higher plants but are common among the plants of the lowly type. *Banger Chhata* and *common chhata* are examples of this type of plants. As they are not to acquire their food through the help of green colouring matter they are devoid of it.

(6) **Insectivorous** or **Carnivorous plants** absorb their food from the captured insect bodies in addition to other food materials derived from soil and air like ordinary plants. Their leaves are modified in such a way that they can easily entrap insects to be used as their food. *Pitcher*

plants, *sun-dew*, *bladder-wort*, are examples of these. (For description consult Physiology).

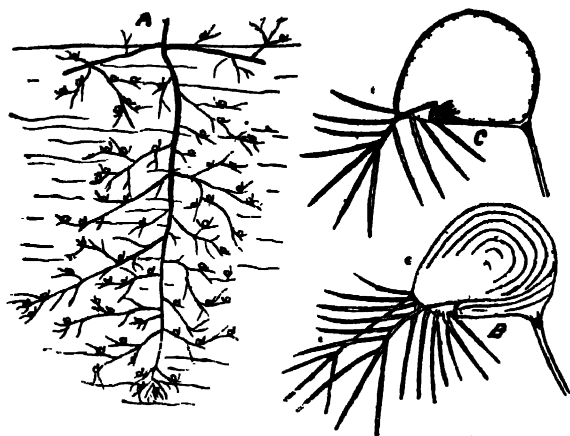


Fig. 7.

Bladderwort plant.

A—The plant. B and C—The bladder-like traps for capturing insects from water.

General morphology of plants.

In all higher plants there are two distinct regions of the plant-body *e. g.* **root** and **shoot**. Root goes into the soil to fix the plant there and shoot grows up in air producing branches and leaves. The axis on which leaves, branches etc. develop is the **stem**. It goes on growing and when the time of reproduction comes, flowers arise on



Fig. 8.

A—*Tishi* plant, B, C—Flowers. a—Root. b—Stem. c—Leaf. d—Branch. e—Flower. f—Fruit.

it. Stem along with branches, leaves etc. serves the nutritive or vegetative functions and thus it forms the **vegetative shoot** of plants. Stem with flowers, fruits and seeds carries on a different function *i. e.* reproduction and so it forms the **reproductive shoot** of plants. The different parts into which the plant-body is divided are called **members.** Each member is an **organ** when it serves a particular function.

Plants may be **herbs, shrubs,** or **trees.** Herbaceous plants are usually soft. When herbs grow only for one year or season within which they finish the whole course of their lives, they are **annuals** as *matar, dhan.* When the duration of the lives of plants is for two years or seasons they are called **biennials** as

beet Plants growing for more than two years or seasons are called **perennials** as *tal* All annuals and biennials are herbs. Perennials may be herbs when their stems remain underground as *kala*, *ada* etc. Shrubs are generally low and much branched at the base so that they are bushy in appearance as *jaba* Trees have very woody stems, and the distinct trunk does not develp branches at the base as, *bot*, *am*, etc Trees can not be very sharply distinguished from tall shrubs

Tabular Summary of the above types of plants :

	Plants	Sources of food	Organs of absorption	Examples
1	Land plants	1 Soil 2 Air	Roots Leaves	*Golap Am*
2	Water plants — Floating	1 Air 2 Water 3 Soil (in some cases)	Leaves Stem Roots (in some)	*Podma* *Pana*
	Water plants — Submerged	1 Water 2 Soil	Stems leaves and roots	*Patashaola*
3	Epiphytes	Air	Aerial roots and leaves	*Rasna*
4	Parasites — Total	Host plant	Haustoria	*Swarnalata*
	Parasites — Partial	1 Host plant 2 Air 3 Soil	Haustoria, leaves and roots	*Manda*
5	Saprophytes	Decomposed organic matter	Whole plant or part of it	*Banger chhata*
6	Insectivorous plants	1 Insect bodies 2 Soil or water 3 Air	Leaves (modified) and roots	*Pitcher plant*

Exercise I

1. Give some idea of the main divisions into which the plant kingdom is divided. Define the divisions in a general way (C. U. 1910.)

2. What is a parasite ? Distinguish the parasite from the saprophyte. Give examples (C. U. 1913.)

3. Describe the meaning of the terms—epiphyte and thallus. (C. U. 1919, 1921.)

4. Classify plants according to their different modes of nutrition.

CHAPTER II

GERMINATION

Parts of the seed.—As we are concerned with seeds for the study of germination let us be acquainted at first with the different parts of seeds in general. All seeds must have a **covering** for the protection of the inner portion called **kernel** of the seed. The covering or seed-

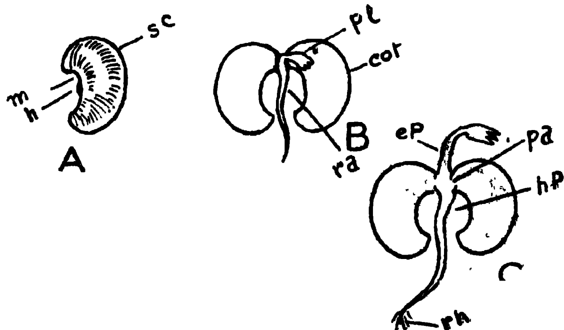


Fig. 9.

Parts of *barbati* seed. A—seed. Sc—seed coat. h—Hilum m—Micropyle. B—When the coat is removed. Pl—Plumule. Cot—Cotyledons. ra—Rdicle. C—The seed during germination. Hp—Hypocotyl. Ep—Epicotyl. Pa—Point of attchment of the axis with the cotyledons.

coat usually consists of two layers closely attached to each other. The outer thick layer is **testa** and the inner thin layer is **tegmen**. At one side of the seed-coat there is a scar

called **hilum** which represents the position where the seed was attached to the stalk. Near the scar a minute aperture called **micropyle** can be detected by gently pressing a soaked seed between the fingers when water is found to ooze out from the micropyle.

When a pea seed is placed in water for a few days the seed is found to swell up and become soft. On peeling off the seed-coat it is found to consist of two layers which are known as the testa and tegmen of the seed. Within this coat two large fleshy bodies are seen placed one opposite the other. These are the **cotyledons** or seed-leaves. The small white conical body on one side of the cotyledons is the **radicle** or the embryonic root. The apex of the radicle points towards the micropyle. Continuous with the radicle and placed between the cotyledons is found the **plumule** or the embryonic shoot. On using a lens this is found to consist of a number of minute leaves. The *cotyledons*, *radicle* and *plumule* collectively form the **embryo** or the minute plant of the seed.

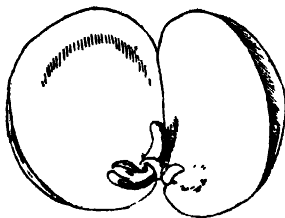


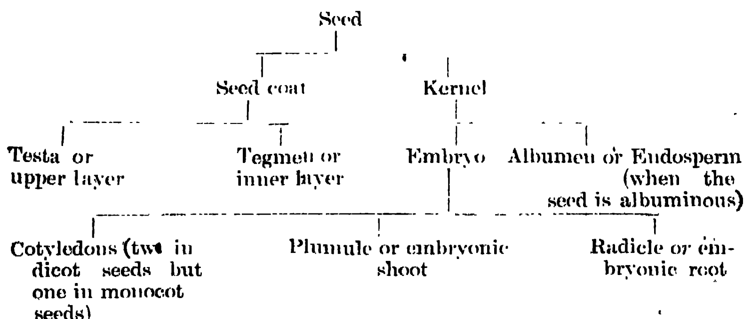
Fig 10
Pea seed showing cotyledons, plumule and radicle.

In some seeds as *shim*, *tentul*, *chhola* etc. the embryo forms the entire kernel of the seed. These are called **exalbuminous** seeds. In many seeds of monocots such as, *dhan*, *gom* etc, the embryo is very minute and occupies a small portion of the kernel. The major portion is occupied by a white mass called **albumen** or **endosperm** which is a reservoir of stored food to be utilised at the time of germination. These seeds with endosperm in addition to

embryo are called **albuminous**. Dicot seeds may be albuminous as, *rerhi*, *dhania* etc. or ex-albuminous as, *kumra*, *tentul*, *pulses* etc.

The plumule and radicle together form an axis of the embryo. This axis is attached to the cotyledons at one point. If there is a distinct part between the radicle and the cotyledons it is called **hypocotyl**; and a similar distinct part between the plumule and the cotyledons is called **epicotyl**. (Fig. 9, C)

The relation of the different parts of any seed can be represented in the following table.



Germination : its meaning.—By germination of the seed we mean the sprouting up of seedling from a seed due to the development of embryo in the seed. Before germination takes place, the embryo, though living, remains inactive in the seed and does not seem to breathe. It is thus as if in a sleeping mood. The process of germination awakens the embryo from its sleeping condition so that it can now lead a life of activity and growth. Now it also goes on respiring vigorously and

rapid changes are seen to occur in the entire body of the embryo till it is converted into a seedling capable of acquiring food materials from the soil and air with the help of newly developed roots and leaves. All these changes resulting in the conversion of an inactive body to a self-supporting structure are due to the process of germination.

Conditions for germination.--In the life of a flowering plant seed is a resting stage. At the time of seed formation activity is great but when the formation is complete and the seed is mature, it takes rest *i. e.* it remains as a dormant body for a few months and even years. So long as the resting period is not over, germination fails although the conditions for germination are supplied to it.

Changes usually take place in a dry mature seed when it is placed under the influence of several favourable conditions. They are (1) **Water**, (2) **Oxygen** and (3) **Heat**.

Water, when absorbed by the seed, softens the seed-coat, however hard it is. The stored food is usually insoluble. This is rendered soluble during germination by the action of a ferment. The soluble food makes a solution when it comes in contact with the absorbed water. The solution is then easily transferred from the store-house to the growing regions of plumule and radicle. The oxygen necessary during germination is only required for the respiration of the young plants while heat is the source of energy necessary for germination.

Seeds always require for their germination **suitable amount** of water, oxygen and heat. But when they are supplied with, too much or too little, heat or moisture germination fails. In the same way, the entire absence of oxygen in the soil prevents germination.

Light is not necessary during germination. Rather, when light is strong it may hamper germination. In that case the germinating seeds ought to be screened. Light is highly useful immediately after germination as new leaves can neither be green nor can they absorb food from the air when deprived of light.

To prove that germination is possible only with the suitable amount of moisture.

A short stick is put slantingly in a large beaker half-filled with water. Three soaked bean seeds are attached to the stick at different parts namely, one within the water, the second outside the water and the third just on the surface of water. The water is boiled to exclude the dissolved air and then allowed to cool. Germination fails, in the first for want of oxygen and in the second for want of water while the third getting both suitable amount of water and oxygen germinates vigorously.

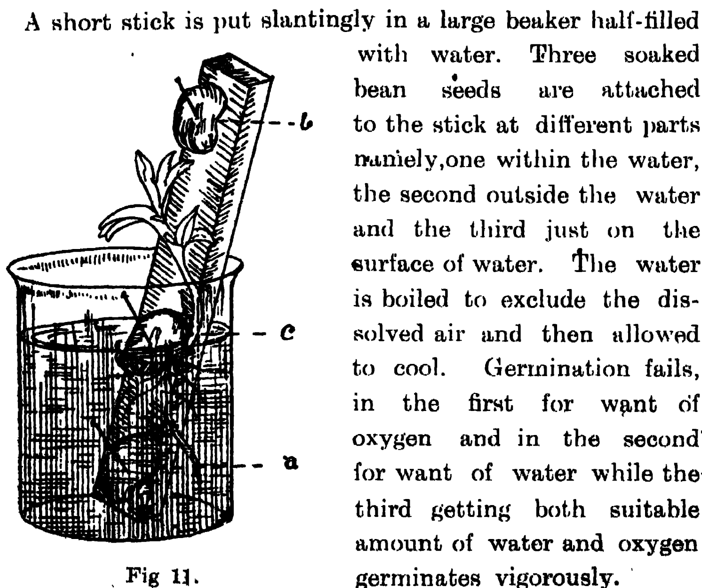


Fig 11.

Three bean seeds germinating in different regions of a stick. a—Seed placed in water. c Seed placed on the surface water. b—Seed placed far above water.

Changes during germination.—When a dry seed is placed on a moist place it absorbs a large amount of water and swells. Soon the seed-coat bursts at one

point through which the radicle makes its way out of the seed and grows towards the soil where there is no light. When the end of the radicle touches the soil it produces fine hairs called **root hairs**, a little away from the tip. The root hairs now try to fix the developing plant in the soil and absorb food from the soil.

In many dicot seeds as *tentul*, *sharisha*, *kumra*, *rerhi*, *barbati*,etc. the upper part of the radicle or hypocotyl elongates upwards. The force of elongation is so great that at first it is in the form of a loop. The loop is strong enough to pierce through the overlying soil and to drag along with it the cotyledons and the plumule which are pushed in the air while the seed coat is left behind in the soil. The cotyledons now coming to light become green and try to serve as green leaves. These cotyledons are then called **epigeal**. The type of germination in this case is also called **epigeal**.



Fig. 12.
Seed of *Barbati* (bean) germinating.

In other seeds of dicots as, *am*, *kantal*, *matar* etc. the hypocotyl is not so active in growth ; hence the cotyledons are not carried above the soil, but remain on the soil as they were before the time of germination. The cotyledons in these germinating seeds are called **hypogeal.** The pointed free end of the plumule gradually grows np pushing aside the hard particles of soil above it. Thus it is noticed that

when hypocotyl elongates, germination is epigeal and **when epicotyl elongates, the germination becomes hypogeal.**

Germination of several common types of seeds.

(1) Shim or bean seed (Dicot and ex-albuminous). – The smooth, black and oval seed has a white stripe on one of its sides. There is a very minute hole called micropyle at one end of the stripe. When the seed is soaked in water, wiped dry and then pressed gently between the fingers,



Fig. 13.

Different stages of germination of a *Shim* seed. A—Seed. B—Radicle coming out. C, D—Showing hypocotyl in the form of a loop. E—Last stage.

water can be found oozing out from the micropyle. There are two coats—the thick outer one and the thin inner

one. When they are removed, the whole white mass exposed is the embryo of which the radicle lies at one of its edges as a conical protuberance. The mass can easily be separated into two large fleshy bodies, called cotyledons. They are connected at one side with the radicle. The feather-like plumule lies between the cotyledons which are the storehouses of food for supplying the plumule and radicle at the time of germination.

When water is supplied to the dry seed, it takes several hours to soften the hard coat. At first the radicle comes out of the swollen seed as a white pointed body which grows towards the soil and produces fine root hairs from its end. Soon the hypocotyl elongates and bends on account of the considerable growth at that region. It is in the form of a loop, one end of which is within the soil and the other end is within the cotyledons which are thus gradually pushed out of the soil. The bent head freed from soil tries to be straight after throwing off the seed coat. Plumule now begins to grow as a new shoot above the cotyledons. Hypocotyl is at this stage a long portion of the axis lying between the cotyledons and the surface of the soil. Thus **the germination is epigeal**.

(2) Mango seed (Dicot and ex-albuminous).—The stony covering is not the seed coat but the last layer of the fruit known as the **endocarp**. This encloses within it the entire seed. The seed coat consisting of testa and tegmen forms a thin membrane closely attached to the inner wall of the endocarp which bursts at one side through which the radicle makes its way. Soon the radicle becomes established in the soil, as a strong root producing branches.

The epicotyl now grows very vigorously and thus forces the plumule to grow out of the cotyledons which remain having its position least affected in the process. The plumule now rising above the soil grows as a 'new shoot on which several long leaves appear which though brown at first, gradually become green in colour. The **germination of the seed is hypogeal.**



Fig. 14.
Mango seed germinating.

(3) Castor seed—(Dicot and albuminous).—The highly polished, streaked hard coat is the testa of the seed. At one end of the seed there is an outgrowth called **caruncle** which covers the micropyle. On removing the testa a white massive body is found. When this is split lengthwise in the plane of the flat side, a small embryo becomes visible. This consists of two cotyledons, a radicle and a plumule. The cotyledons are very thin, leaf-like and surrounded completely by the oily white mass called **endosperm,** in which abundant food is stored for the use of the embryo during germination. The radicle lies towards the caruncle while the plumule lies between the cotyledons.

When the seed is soaked in water for a few days, the

radicle comes out at first. The hypocotyl elongates and grows so fast that it forms a loop and carries the cotyledons, endosperm and plumule above the ground. The thin cotyledons remaining within the endosperm go on absorbing food from it, until all the food-store is exhausted, when they come out, expand and form the first green leaves of the new plant. **The cotyledons are thus epigeal.** The radicle gradually develops into a thick primary root.

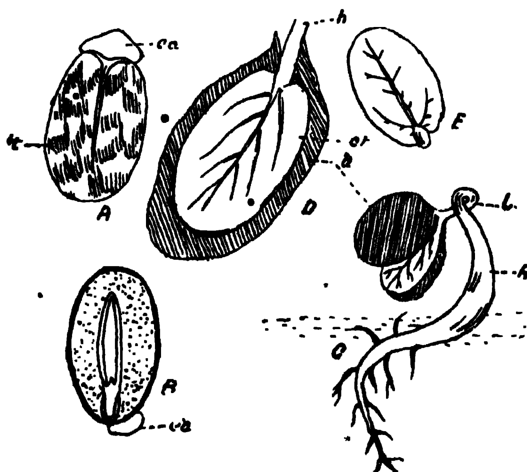


Fig. 15.

Castor seed germinating. A - Entire seed. B—Longitudinal section of the seed. C—Seed germinating and the hypocotyl in the form of a loop. D—Cotyledon with endosperm surrounding it. E—Cotyledon showing the veins. ca—Caruncle. ct—Cotyledon. h—Hypocotyl l—Loop. a—Endosperm. t—Testa

(4) **Paddy**—(Monocot and albuminous).—The whole grain or the unhusked rice consists of the husk and the rice. The husk which serves the purpose of protecting the rice is no part of the seed. The grain is a

single-seeded fruit and not a seed. Paddy can never germinate if this husk is absent during germination. Its presence is essential as it maintains that amount of heat which is required at the time of germination. Similar cases are noticed in *bhutta*, *gom*, etc.

At the base of the grain there are two white minute scales on the two sides embracing the husk. The grain is, in some cases, crowned by a bristle-like body, called **awn** which helps in fixing the germinating grain to the soil. On removing the husk, the small embryo is found to lie on one side of the grain occupying a small part of it. The greater portion of the grain is occupied by the mealy endosperm which contains abundant stored food to be utilised by the embryo when germination goes on. The embryo consists of plumule and radicle besides a single cotyledon which is in the form of a sheath and one surface of which lies in close contact with the endosperm. This peculiar cotyledon known as **scutellum** acts as an organ for absorbing food from the endosperm. Within the husk and adjacent to the white scales of the grain, lies the radicle covered by a sheath called **root-sheath** which is an extended part of the scutellum. The plumule lying above the radicle consists of a series of very small rudimentary leaves of which the outermost, sheathing the inner ones, is a part of the scutellum.

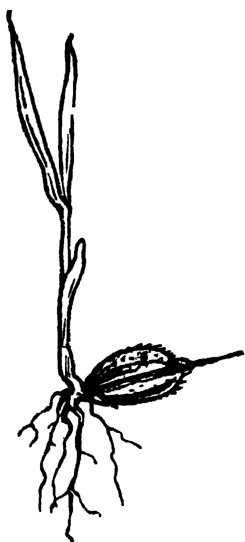


Fig. 16.
Paddy seedling.

When the grain is placed on moist soil, it goes on absorbing water. The radicle first passes out of the grain and grows downward, breaking through the root-sheath. It does not develop further but withers away and is replaced by many fibrous roots, derived from the base of the plumule. In the meantime, the plumule, covered by the leafy sheath, pushes its way upwards and when it is above

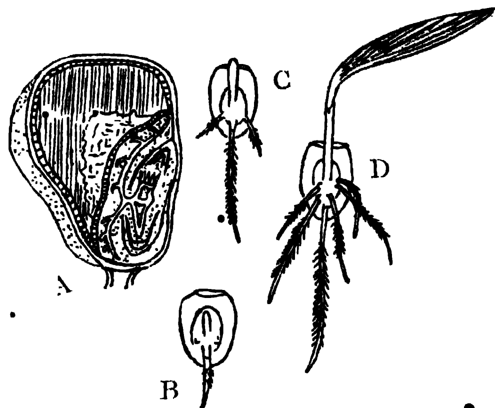


Fig. 17.
Germination of *Bhutta*. A – Longitudinal section of *bhutta* grain.
B, C and D—Different stages of germination.

the soil the sheath bursts to allow the first leaf of the plumule to expand into the air. So long as the food is present within the endosperm, the cotyledon goes on absorbing food in the form of solution and supplies that to the growing parts of the plumule and the roots. **Germination thus is hypogeal.** (cf. the germination of *bhutta*).

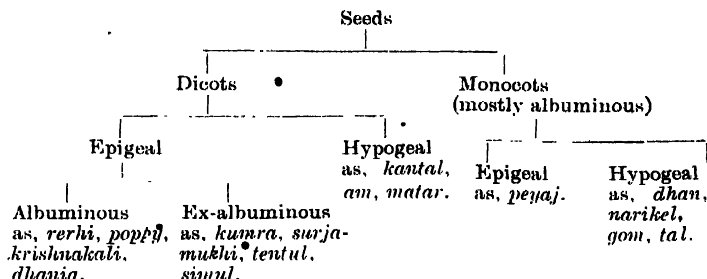
(5) **Cocoanut.**—(Monocot and albuminous).—This is a fruit consisting of three layers of which the last is stony, as in mango. They are helpful at the time

of germination. The stony layer is the shell that covers the seed. The seed coat is thin and brown lying adherent to the shell. The white edible kernel containing the cocoanut milk is the endosperm of the seed. The embryo is very minute and is buried in the white solid endosperm just below the eyes which can be noticed at one end of the shell. The embryo consists of one cotyledon, a small radicle and a plumule, and is well provided with a thick layer of white endosperm.

When germination begins, the cotyledon becomes spongy, ball-like and bigger in size. Gradually it fills up the cavity of the endosperm and goes on absorbing food both from the milk and the solid endospern. One of the three eyes of the stony layer which marks the position where the embryo lies buried in the endosperm allows the germinating seed to bore its way through the hard stone. The radicle soon dies away and from the base of the plumule many fibrous roots appear, penetrate the husk of the fruit and grow down to the soil from which they draw water and food. Meanwhile the plumule ruptures the enveloping sheath and grows upward to produce green leaves. So long as the endosperm is not exhausted, the cotyledon remains within it. **Germination is thus hypogeal.**


Fig. 18.
Cocoanut germinating.

Seeds with different modes of germination.



Difference between Dicot and Monocot seeds and their germination.

Dicot seeds.	Monocot seeds.
1. Albumen may be present or absent.	1. Albumen usually present.
2. Cotyledons two in the embryo.	2. Cotyledon only one.
3. Germination is epigeal or hypogeal.	3. Germination is usually hypogeal.
4. Hypocotyl or epicotyl pushes the plumule out of the seed.	4. Cotyledon itself pushes the plumule.
5. Cotyledons are lateral and plumule is terminal.	5. Cotyledon is terminal and the plumule is lateral.
6. Radicle is not replaced by other roots.	6. Radicle is replaced by many fibrous roots.
7. Radicle persists to develop into a normal root.	7. Radicle does not persist and hence it does not develop into any primary root.

Functions of cotyledon.

1. In ex-albuminous seeds, they store up food in them and hence they become fleshy or massive in form.

2. They protect the plumule and radicle.

3. When epigeal, they act as green leaves.

4. As a scutellum, the cotyledon draws food from the endosperm to supply it to the plumule and the radicle.

In monocot seeds, the cotyledon pushes the plumule out of the seed.

Exercise II.

1. What is an albuminous seed? Describe the structure of a dicotyledonous albuminous seed. Give an example with sketches—C. U. 1933.

(**Hint** :—Rerhi or castor is one of the Dicot albuminous seeds. For the description consult page 22).

2. Compare the structure of the seeds of the maize and the bean. Show in what respects they differ from one another.—C. U. 1924.

3. What do you understand by the germination of seeds? Illustrate your answer with reference to tamarind seed.—C. U. 1922.

✓ 4. Describe the mode of germination of any common seed as pea or bean or the seed of any common fleshy fruit. What are the essential factors for germination? —C. U. 1921, 1920, 1909.

5. How would you demonstrate the essential conditions required for the germination of seeds? —C. U. 1929.

6. Describe the germination experiments that you may have performed in your practical course. Give the method as well as the purpose of each experiment and state the results obtained. —C. U. 1923.

(**Hint** :—Regarding the purpose of the experiments, state the utility of supplying the embryo with the favourable conditions. As regards the results, the cotyledons may be epigeal or hypogeal).

7. Describe the germination of a Monocot seed with an example and neat sketches.—C. U. 1933.

(**Hint** :—Paddy may be selected. For description see page 23)

8. Describe from your own observation and contrast the germination of any Dicot seed with that of any Monocot seed.—C. U. 1911.

(**Hint** :—Take bean as the type of a Dicot seed and paddy as the type of a Monocot).

CHAPTER III

ROOT

Characteristics of roots.—Root is the descending axis of the plant as it grows downward into soil where there is no light. It is usually non-green in colour, for it lies buried in the soil and is not exposed to light.

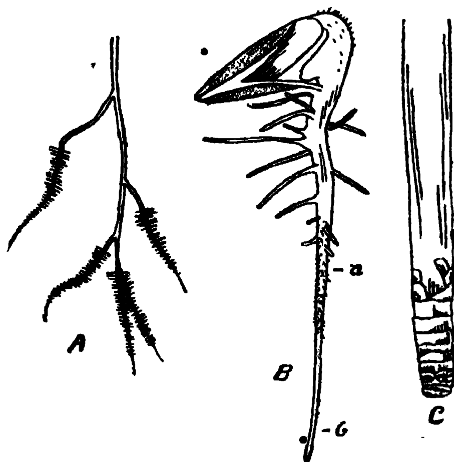


Fig. 19.

Roots. A—Branches of root with root hairs. B—*Kumra* root. a—Root hairs. b—Root cap. C—*Kea* root with root-cap.

When it penetrates deeply in the soil it produces branches in a regular order of succession, i.e. the older branches are at

the base and the younger branches are at the apex. The branches on the main root are called **secondary roots.** They in their turn produce another set of branches called **tertiary roots** and so on. Roots usually bear branches. Leaves and leaf-buds are not found to develop on them. The branches of a root arise from the deeper parts of it. They are thus known as **endogenous** in growth.

At the extreme tip of the roots or their branches, they are covered by a cap-like body called **root-cap**. As the root is very delicate at its tip, the root-cap protects it. This is also very sensitive to moisture and food in the soil and due to this property it can easily trace regions of soil where the food for the plant is available. It can guide the root towards those directions where the food is present in the soil.

A little behind the root-cap there is a portion of the root from which fine hair-like bodies called **root-hairs** develop. These hairs directly absorb food from soil by closely adhering to the soil particles. They also fix the root in this way to the soil.

Kinds of roots

When the radicle persists, continues to develop and produces on it branches, it is known as **true root** or **tap root**. The main or primary root with its different sets of branches forms the **root system**.

Sometimes roots may develop from any other part of the plant than the radicle. These are called **adventitious** or **false roots**. Most of the Monocot plants produce this form of roots. Besides them, the roots arising from the

branches of *bot* or from the leaves of *patharkuchi* are all adventitious.

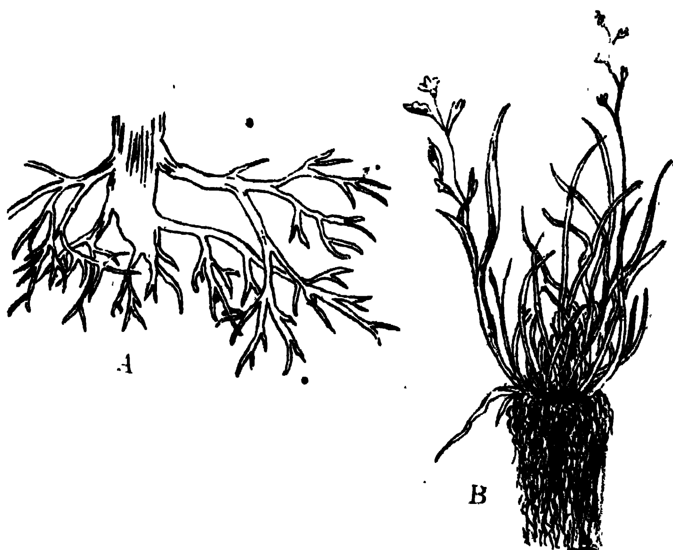


Fig. 20.
Root. A - Normal root. B - Adventitious fibrous roots.

The roots of annuals consist of a cluster of hairy bodies which are not so deeply penetrating. They gather food from the upper layers of the soil. Roots of *ghas*, *dhan*, *gom* are of this type. These are called **fibrous roots**.

Fleshy roots store food in them and are of varying forms. The stored food is meant for the future use of the plants. They may be :—

(i) **Conical**, as *gajar*, when they are broad at the base but gradually tapering towards the apex.

(ii) **Fusiform,** as *mula*, when they are more or less tapering towards the two ends, but slightly swollen in the middle.

(iii) **Napiform,** as *shalgom*, when they are considerably swollen, but suddenly tapering at their tips, as in the form of a top.

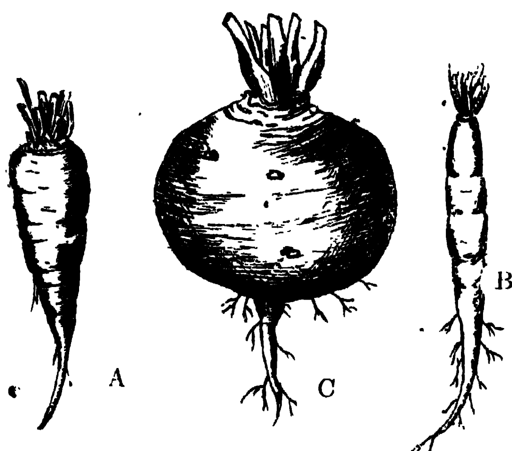


Fig. 21.
Fleshy roots. A—Conical root of *gajar*. B—Fusiform root of *moola*. C—Napiform root of *shalgom*.

These three forms belong to biennials, though some of them finish the whole course of their lives in one year in this climate.

(iv) **Tuberous**, as, *shankalu*, *rangaalu*, *shatamuli* etc. where they consist of one or several swollen bodies arising in a cluster.

Besides these, there are other types of roots, where their forms become modified in accordance with the functions they



Fig. 22.
Tuberous roots of *shatamuli*.

are to serve. So they can be mentioned in connection with the functions of roots.

Root functions

(A).—Normal functions.

(1) Roots fix the plant to the soil where it grows.

(2) Roots absorb food from soil through the help of their root hairs.

(B).—Secondary functions.

(1) Roots store food in them in some cases for future use and for this reason they become **fleshy** and very massive in form as stated before.

(2) In some climbing plants, as, ***pan***, ***choi***, *gajpipul* etc. special forms of roots called **climbing** or **clinging roots** develop from their stems to help them in climbing up any support on which they can grow.



Fig. 23.
Adventitious roots. A—Clinging roots of *pan*.
B Floating roots of *keshardam*.

(3) We have noticed before that epiphytes produce special **aerial roots** by which they absorb their food from air. These roots remain suspended in air and absorb moisture from it. (See fig. 5).

(4) The roots of parasites called **haustoria** are short bodies developed from those regions where they come in direct contact with their host. They penetrate deeply into their host bodies from which they are to draw the required food. (See fig. 6)

(5) **Aquatic roots** belonging to water plants as, *pana*, *paniphal* etc. absorb throughout their entire surface, the food which remains in solution in water. Hence they are as a rule very soft and whitish in colour.

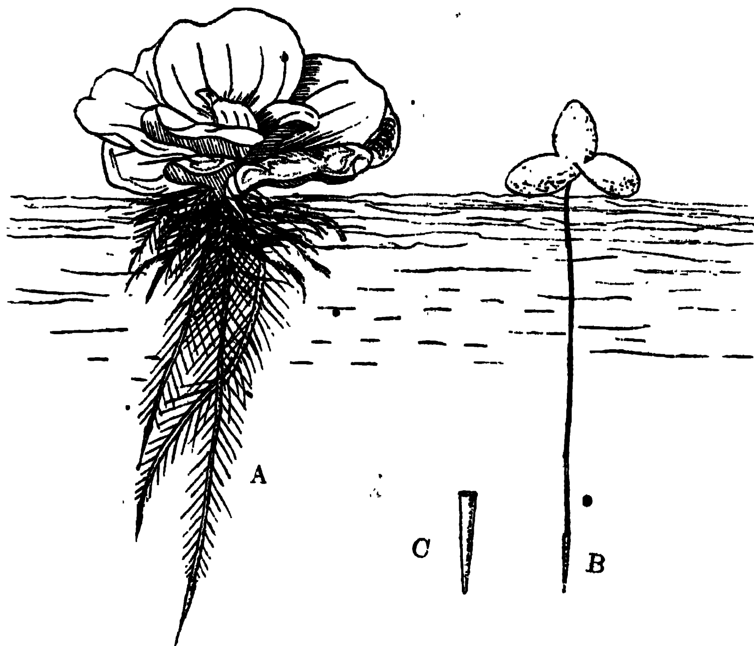


Fig. 24.
Aquatic roots. A—*Barapana*. B—*Khudipana*.
C—Root-cap.

(6) The **floating roots** or **floaters** of *keshardam* are white spongy bodies developed from the stem in a cluster. They are filled with air which makes the whole plant light so that it can float easily on water and enjoy sunlight as fully as possible. (fig. 23)

(7) **Prop roots** are pillar-like aerial roots of *bot* which grow from the main stem or the horizontal branches.

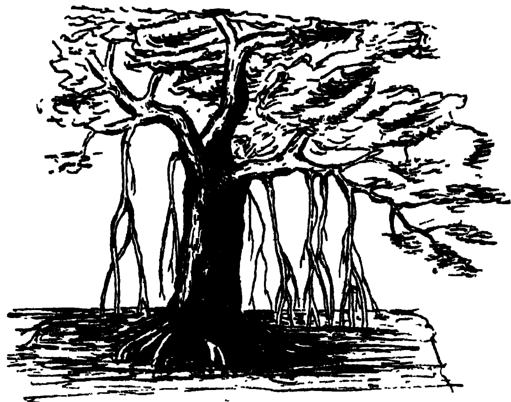


Fig 25.
Prop roots of *bot*.

They act as supports for those branches which can thus grow vigorously for a long distance. Some of these aerial roots grow in the air without any contact with the soil. They remain as hanging bodies without lending any help to the branches like the prop roots.

(8) **Stilt roots** are stilt-like bodies developed from the base of the stem so that the primary or main stem rests upon them as in *kea*. They differ mainly from the prop roots in this that they are the supporters of their trunk instead of the branches.

(9) **The thorny roots** of *tal*, *narikel* and other palms grow among the fibrous roots to fix the plant more firmly to the soil.

(10) In some cases, roots become **green** in colour by developing in them the green colouring matter, when they grow out of the soil and are exposed to light, as the roots of *gulancha*.



Fig. 26.
Stilt roots of *kea*.

(11) **Respiratory** or **breathing roots** also called **pneumatophores** belong to plants which grow in swamps or marshy places as, *mangrove*, *keora* etc. of the Sunderbuns. As their root system cannot get sufficient quantities of oxygen necessary for respiration, the ordinary roots of these plants lying buried in salt marshes send up into the air special erect roots. They possess pores in them

to allow air to get into the root system. They are specially adapted in growing from the soil with their tips out into the air instead of spreading in the mire. The spongy erect roots of *keshardam* have

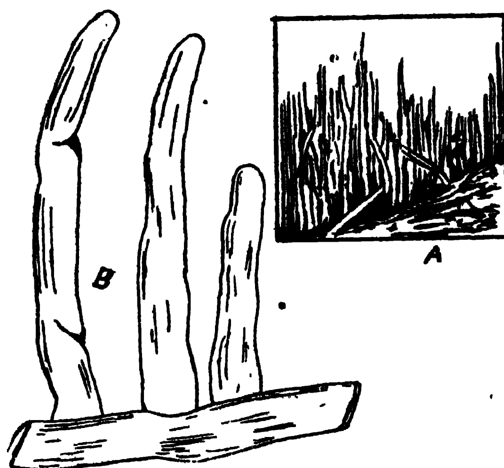


Fig. 27.

Respiring roots of Mangrove. A – Many roots on the sea-beach. B—Three of such roots growing as erect bodies.

also the breathing function. Sometimes, *dhan*, *ak* etc. also produce breathing roots.

(12) There are numerous plants which can multiply even through the help of roots. Thus when the running advanced roots of *bael*, *nebu*, *jam* etc. be cut off or injured in any way, a little away from the stem, they can give rise to new plants at those cut-end portions which are in connection with the mother plant.

The tuberous roots of *shatamuli*, *shankalu* etc. are sometimes found to propagate plants. Similarly new shoots arise from the roots of *patal*, *kachuripana*, *kurchi* etc.

Tabular summary of different types of roots.

Roots

- Normal
  - Ordinary as, *am*.
  - Modified into fleshy :—
    - (1) Conical, as, *gajar*.
    - (2) Fusiform, as, *mula*
    - (3) Napiform, as, *shalgom*.
    - (4) Tuberous, as, *rangaalu*.
    - (5) Fasciculated - Satamuli.
    - (6) Nodulose - ambo-ginger.
    - (7) moniliform - grass (some case).
- Adventitious
  - (1) Fibrous, as, *dhan*.
  - (2) Epiphytic, as, *rasna*.
  - (3) Parasitic, as, *swarnalata*.
  - (4) Aquatic, as, *pana*.
  - (5) Floating, as, *keshardam*.
  - (6) Climbing, as, *pan*.
  - (7) Thorny, as, *narikel*,
  - (8) Respiring, as, *chura*.
  - (9) Prop-like, as, *bot*.
  - (10) Stilt-like, as, *kea*.

Exercise III

1. What are the characteristics of a root ? What are its functions ? What are adventitious roots ? — C. U. 1932, 1928.

2. What are the normal functions performed by roots ? Show how the structure of the root is modified in relation to special functions. —C. U. 1915, 1911.

CHAPTER IV

STEM

General Characters It is the ascending axis of the plant. It grows towards light and air. It usually bears leaves, buds, branches or modifications of all of them. It becomes green in colour and hence it has the power of absorbing food materials from air. The branches, leaves, etc. are developed on it from the superficial regions so the growth of stem is exogenous.

The region on the stem where leaves arise, is called the *node*. The space of the stem between any two successive nodes, is called the **inter-node**. The leaves never arise from this internodal region. The inner angle which the stem or its branch makes with the leaves at the node, is called the **axil**. A bud usually appears at the axil and may grow out into a branch in due course.

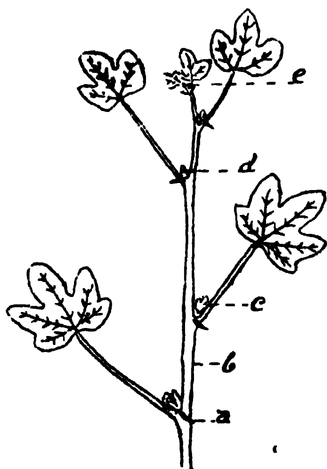


Fig. 28.
Parts of a stem, a - Node. b—Internode. c - Bud. d—Axil. e - Bud at the head.

In some cases, the inter-nodes are more or less suppressed in development, so that the stem becomes so dwarf, that it can not be distinguished easily. The leaves from the successive nodes of such a stem arise as if in a cluster. Such apparently

stemless plants are called **acaulescent** as, *bhumichampa*, *pana*, *anaras*, etc. During the flowering of these plants, a long stalk, called **scape**, arises to bear flowers and fruits.

Distinction between typical roots and stems.

ROOT.	STEM.
1. Descending axis of the plant.	1. Ascending axis of the plant.
2. Grows away from light and towards soil.	2. Grows towards light and away from soil.
3. Usually non-green in colour, so can not absorb food materials from air.	3. Green in colour and can absorb food materials from air.
4. Bears only branches..	4. Bears leaves, buds and branches.
5. Branches are endogenous in origin.	5. Branches, leaves, etc. are exogenous in origin.
6. Apex is covered by a root-cap.	6. Apex has a terminal bud.
7. Root hairs are usually present, unicellular and nutritive.	7. Hairs, when present, are protective and multicellular.

Functions of stem.

Stems, bearing leaves and branches on them, arrange and spread them out in such a position that they can enjoy air and light fully. When stems grow in age, they become thicker and stronger to carry the whole burden of the foliage. Stems also help the conduction of raw food materials in solution from the roots to the leaves. The prepared food again passes through the stems, from the leaves to the different parts of plants. Stems bear flowers and frnits, so that they may be freely exposed to air and light and thus may attract insects, birds, etc. Stems may also store surplus food matters in them, which are utilised in future, when occasion arises.

BUD

Bud is a shoot in the first stage of its development. Its axis consists of distinct nodes and internodes. Undeveloped leaves arise from the different nodes in such a way that they form a crowded mass. The internodes are very short and have not yet become elongated. Bud is thus an undeveloped shoot which, when develops and unfolds, gradually grows out into a leafy twig consisting of nodes, internodes and leaves.

Structure of the bud.—Unlike roots, the apex of the stem is never covered by a cap. There is a compact structure at the head of the stem or branch which when cut longitudinally is found to consist of many loosely arranged leaves. On observing closely it shows that just at the tip there is an outgrowth which is accompanied by two similar outgrowths, on its two sides. These three are covered by a pair of leafy outgrowths, arising from the two sides of the axis. Beneath these undeveloped leaves, are again two outgrowths on the two sides which along with those at the head, are covered by two more developed leaves

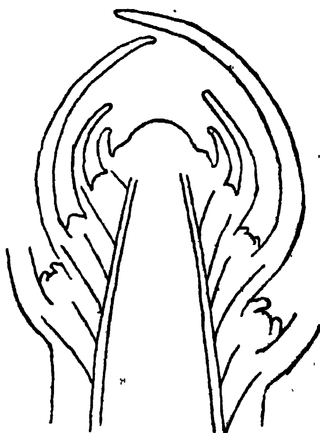


Fig. 29.
Longitudinal section of a bud

and so on. The internodes of the axis become more and more elongated towards the base and the nodes give rise to leaves which are more and more expanded in form, from the base of the stem upwards.

Kinds of buds.—The result of the development of buds is the formation of branches or flowers on the plant. The buds producing branches are called **foliage buds** and those giving rise to flowers are **flower buds**.

Mainly there are two kinds of buds, viz. (1) **Normal** and (2) **Adventitious**. **Normal buds** are usually situated at the axils of leaves, when they are called **axillary buds**. They also occur at the ends of branches or stems, when they are called **terminal buds**. Some of the axillary buds specially those of cold climates remain dormant for sometime, i. e. the power of growing out into branches, remains latent in them, for a long time. They are known as **dormant buds**. In ordinary buds, the protective leaves, at the axils of which buds grow, develop along with the development of their buds. So, by the time the leaves, after their full growth, wither and fall away, their active buds grow out into branches. But the dormant buds do not grow along with the growth of the subtending leaves. They lie dormant even when the leaves are

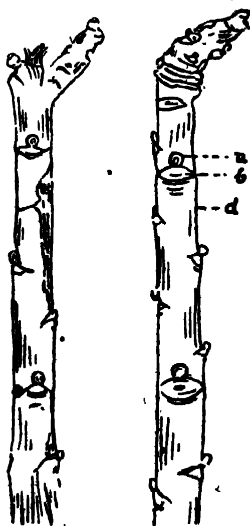


Fig. 30.
Normal buds of *simul* in February. a—Axillary bud. b—Node. c—Terminal bud. d—Internode.

absent and do not protect them. In the absence of these leaves, when they are exposed to the rigours of weather, protection is afforded by the development of scaly leaves on the outer surface. Sometimes, a thick coating of hairs or resinous secretion on the buds may serve the purpose. These forms of scaly or hairy buds can be found in *asoka*, *bans*, *bot* etc. Some dormant buds remain, for a long time, hidden and they are protected by the overlying bark as in *kantal*, *bakul*, *shishoo*, *kamranga* etc.

Adventitious buds are never found at the axils of leaves, as normal buds stated above. Being thus disconnected with the leaf-axils, they grow irregularly from any part of the plant. They are well-noticed at the indented margins of the leaves of *patharkuchi*, when they are mature and fall on the moist soil. Such buds may be called **epiphyllous.**

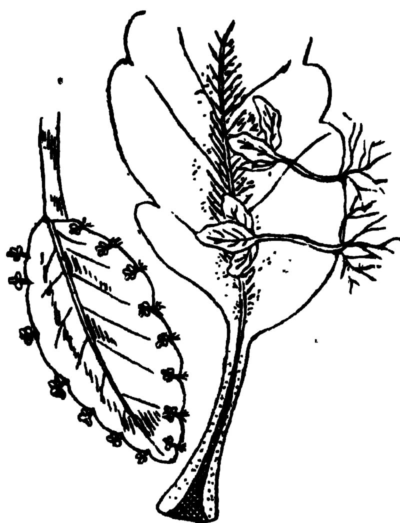


Fig. 31.
Buds on *patharkuchi* leaves.

Gardeners usually pollard or cut off the ends of branches of some plants every year as, *mehdi*, *hesnahena*, etc. Within a few months of pollarding, the cut-ends of branches produce many minute adventitious buds which grow out into many new branches at the time.

Such buds springing from any part of the stem are called **cauline**, as distinguished from epiphyllous buds.

Buds, under special circumstances, may be produced from roots. When a tree is cut down at the base or broken down by storm, roots, instead of producing new root-branches, produce buds which soon grow out into leafy shoots. Such adventitious buds may be called **radical.** Budding power of roots is utilised in the propagation of plants by gardeners.

Sometimes instead of a single bud, two or more buds may appear from the axil of a leaf, as *mehdi*, *ishermul*, etc. In most cases, all of them do not grow out into branches. These are called **accessary** or **additional buds**. In *mehdi*, the upper bud grows out into a thorn.

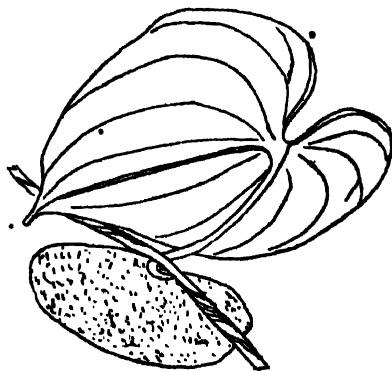
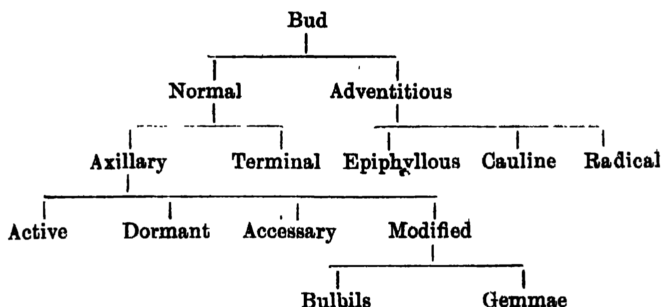


Fig. 32.
Bulbil of *chupri alu*

Buds may be modified into globular swollen bodies, called **bulbils**, at the axils of leaves. They store food in them and, when mature, detach themselves from the parent plant, to produce new plants like seeds. *Chupri alu*, *kandapushpa* (Globba bulbifera) produce buds of this type. In the Cryptogams, as Ferns, Moss, they may reproduce themselves vegetatively by means of modified buds called **gemmae.**

Tabular summary of the types of buds



BRANCHING

Stems produce both branches and leaves on them. The branches are similar to stems in structure, growth and function, but the leaves are in no way similar to them. Branches, thus, are similar, while leaves are dissimilar bodies, developed on stems. The arrangement of similar divisions of stems is known as **branching.**

Types of branching. There are two chief types of branching :—(A) **Dichotomous** and (B) **Lateral.**

When the growing point of any stem divides itself, into two parts, which grow in two different directions forming branches of the stem and when the branches again divide in a similar way, the branching is called **dichotomous**. This is mostly found amongst the lower plants and in some flowering plants. When the divisions of branching are equal and the two branches always grow with equal vigour, it is called **normal dichotomous**. But when the divisions are unequal, so that the branches are not equally vigorous, i. e.

in each division, one branch is stronger than the other and it is the strong branch which is to divide again to form two branches, one of which is stronger than the other and so on, this is called **sympodial branching**. When sympodial, if the strong branches, formed as the result of unequal divisions, are thrown always on one side, namely right or left, it is called **helicoid** or helix-like. But when the strong branches are arranged, after divisions, alternately right and left, so that the axis takes a zigzag course, it is called **scorpioid** or scorpion-like.

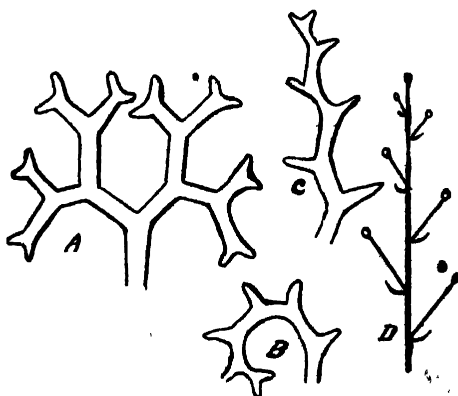


Fig. 33.
Forms of branching. A—Dichotomous. B—Helicoid. C—Scorpioid. D—Racemose.

The branching is **lateral**, when the axis goes on growing upwards with a terminal bud at its head, producing side-branches which originate from lateral buds. This type is common in the flowering plants.

Dichotomous and lateral types compared.

DICHOTOMOUS	LATERAL
1. Branches are formed by the divisions of the growing apex itself.	1. Branches develop a little behind the growing apex of the shoot
2. Branches usually have no connection with the leaf-axils.	2. Branches take their origin from buds at the leaf-axils.

Racemose and **Cymose** are the two types of lateral branching.

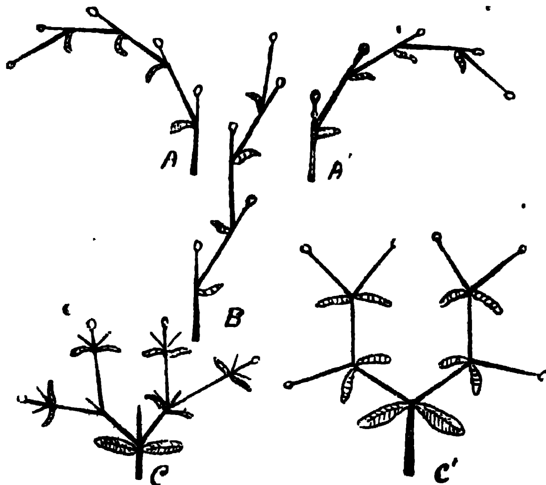


Fig. 34.
Cymose branching. A, A' - Helicoid cyme. B-- Scorpioid cyme. C--Biparous cyme. C'--False dichotomy.

In **racemose** type, the axis continues to develop upwards and produces side-branches on it, arranged in regular order of succession, so that, newer and newer branches are at the top of the axis. This is found in many Dicot plants as, *sharshe,*

moola, *shimul*, etc. As there is no knowing, where the growth of the axis stops, the racemose is also known as **indefinite**. Trees with this type of branching usually become pyramidal in form.

In **cymose** type, the axis can not develop further, when the lateral branch or branches, originating from the axis, begin their development; so, in this type, the lateral branches grow more vigorously than the axis from which they take their origin. There are many shrubs, as, *begoon*, *lanka*, *aswagandha*, etc. which become bushy in form due to their cymose branching. *Shirish*, *deshibadam*, etc. are trees which grow cymosely. Cymose is also known as **definite**.

The lateral branches may arise singly from the axis or two at a time or more. According to the number of branches formed, cymose may be **uniparous**, **biparous** or **multiparous**. In uniparous cyme, when the branches are always developed on one side, it is called **helicoid cyme**. But when the branches are placed alternately right or left, it is called **scorpioid cyme** as, in *dhutra*, *hatishur*.

In **biparous** cyme, branches are formed two at a time as, in *tulshi*, *katchampa*, *krishnakali*, etc. This type appears like a dichotomous one when the undeveloped axes die away and fall off. This is then known as **false dichotomy**.

In **scorpioid** cymose branching, the axillary branch grows so vigorously, that it pushes aside, during its growth, the main axis which has given rise to the branch. As the result of this, when the main axes in the different regions are thus pushed aside they appear as branches, whereas the real branches, though seem to form as one continuous piece of axis, are not produced by the same growing point but consist of separate axes derived from the different growing points.

Thus, in *harjora* stem, each tendril-like branch is the main axis, the position of which is occupied by its real branch by pushing it aside. This can easily be determined by the position of leaves on the opposite side of the tendril. This

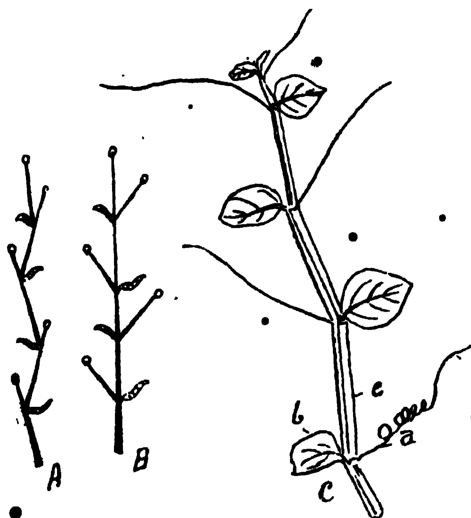
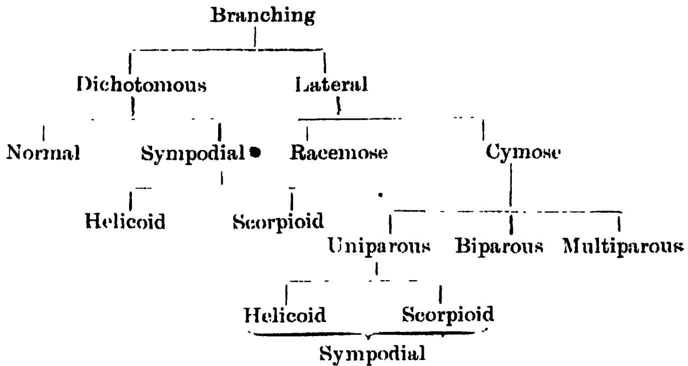


Fig. 35.
Sympodial branching. A—Scorpioid cymose branching. B—When A grows vigorously. C—*Harjora* stem. a—Tendril-like axis pushed aside. b—Leaf. c—Branch growing as main stem.

sort of branching is called **Sympodial**, as the whole continuous axis now formed, consists of separate branches placed one above another.

Helicoid and scorpioid cymes should be carefully distinguished from the **helicoid and scorpioid types of dichotomous branching** We shall deal with racemose and cymose types again in connection with the arrangement of flowers on branches or on the stems.

Tabular summary of branching



KINDS OF STEMS

Underground stems.

There are some stems which grow beneath the surface of the soil instead of growing upwards. They are known as **underground** or **subterranean stems.** They are often mistaken with roots. Like roots they lie buried in the soil. Thus as they are not exposed to light, they are never green in colour and hence can not absorb food from air. Like some fleshy roots they also store food in them which is meant for future use. But though they agree so much with roots, they are never roots but stems, as they have the characters of stems. They bear scaly leaves and buds on them In many of them, the nodes and internodes are distinct. They have no root-cap nor root hairs, so they can not absorb food from soil. Moreover, their internal structures agree with those of stems.

Functions of underground stems

(1). They are the store-houses of food matters.

(2). The buds developed on them are the means by which they multiply vegetatively. This vegetative mode of reproduction is more common among the Monocots than among the Dicots.

(3) They are very weak and soft and are often sought by grazing animals for the sake of the food they contain. Hence they grow beneath the soil to protect themselves from the attacks of animals.

Types of underground stems

They are of four different forms :--

(1). **Rhizome**, sometimes known as **root-stock**, as found in *ada*, *halood*, *sati*, *kala*, *padma*,etc., is a type of fleshy stem growing horizontally as a creeping body beneath the surface of the soil. The nodes and internodes can be distinctly traced on its body. Many adventitious roots are given off from the lower region while there are scaly leaves on it at the axils of which buds arise to develop annually aerial shoots with large green foliage leaves. It continues to develop at the apex within the soil by a lateral bud when it decays in the older



Fig. 36.
Rhizome of *Haluḍ*.

regions. *Mankachu*, *ferns*, etc are vertically growing rhizomes, the top portions of which partially arise out of the soil.

(2) **Tuber** as found in *alu*, *hatichoke* is a swollen, round or oval stem on the surface of which many small pits are noticed, called **eyes** of the tuber. Each eye has a scaly leaf and a bud in its axil. The roots on it are very rare.



Fig. 37.
Tubers of *alu*.

If a little fleshy portion of a tuber, containing at least one of the eyes, be planted on moist soil, it soon gives rise to a new plant. The tuber of *alu* is really an underground branch which becomes fleshy due to the deposition of food matters in it.

Care must be taken that no confusion arises between a **stem-tuber** as, *gole-alu* and a **root-tuber** as *ranga-alu* or *shank-alu*. **When the tuber is a stem, its position is either at the extremity of a shoot or in the axil of a leaf.**

(3) **Corm** as in *ol*, *garden-crocus*, etc. is another type of swollen stem, much branched and more or less flat in shape.

The eyes, as found on the tuber, are totally absent from it but the roots are numerous and grow from all parts of it. The circular, membranous leaves enclose prominent buds in them. Aerial shoots with green leaves grow up from it every year.

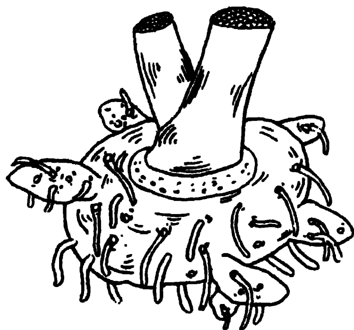


Fig. 38.
Corm of *Ol*.

(4) **Bulb** is a short stem covered by numerous fleshy leaves forming a compact body. It differs from the above three types of stems in having its leaves fleshy. The food is stored

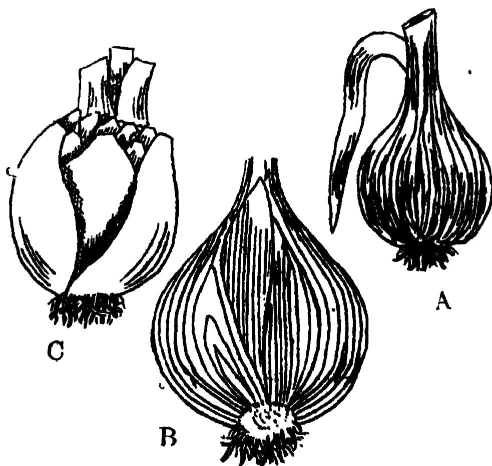


Fig. 39.
A—Bulb of *Piaj* B—Long. section of A.
C—Bulb of *Rajanigandha*.

here within the leaves but not in the stems. It produces

a cluster of fibrous roots from a disc at the base. At the axils of scaly leaves small bulbs arise which when separated from the mother plant give rise to separate new bulbs.

Bulbs may be **tunicated** or **scaly**. When tunicated, as in *piaj*, *rashun*, etc., the outer thin papery leaves cover the inner fleshy ones in a concentric manner. The scaly bulbs have no such outer dry protective leaves. All the leaves here are fleshy and overlap one another as found in *lily*, *rajani-gandha* etc.

Climbing stems

These plants are too weak to support themselves. They can neither stand erect nor can bear the burden of their foliage. Thus they require a support to which they cling

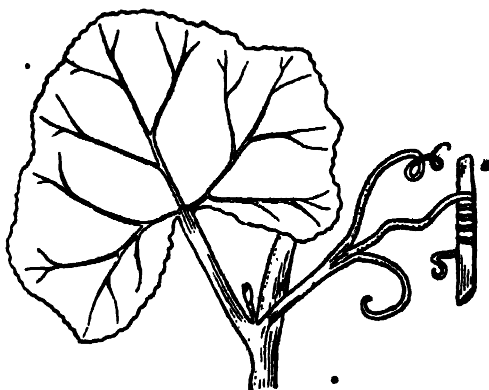


Fig. 40.
Tendril climber of *kumro*.

for getting plenty of air and light. They have thus the special means of growing upwards and of placing

themselves in the most favourable positions for growth and flowering. In the absence of any support they would be prostrate. They have long internodes in order to reach hastily the sunnier region of the atmosphere. The structures they use for the purpose of climbing are varied. According to their organs of climbing they may be of the following types :—



Fig. 41.

Tendril climbers. A—*Ulat-chandal.* C *Mushur-chana.* B—*Shibjhul.*

A. (1). **Root-climbers.**—We have noticed that in *pan*, *choi*, etc. special adventitious roots develop from the nodes and from the shaded parts of the stems. The roots cling to the neighbouring objects and fix the climbers in proper position. (See fig. 23).

(2) **Tendril-climbers,** as, *kumro*, *shasha*, *jhumkolata*, etc. in which the organs of climbing are tendrils which are elongated coiling structures and which are so sensitive at their tips that when they come in contact with any foreign body they go on coiling round it. The tendrils are modified branches when arising in the axils of leaves. They may also be modified leaves called **leaf-tendrils** which are the organs for climbing where the whole leaf or some part of it is adapted for the purpose. Thus the terminal

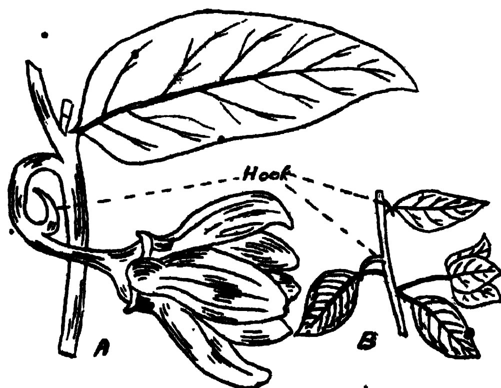


Fig. 42.
Hook climbers. A—*Kantali-champa*. B—*Bagambilas*

leaflets of *matar* leaves, the leaf-ends of *ulat-chandal* and the entire leaves of *mushur-chana* are modified into tendrils. In *shibjhul*, the axis on which flowers arise is a modified tendril. (See fig. 41).

(3) **Scramblers,** as, *golap*, *Leth*, etc., are able to climb by means of prickles scattered irregularly over the surface of stems or branches. In *kahtalichampa*, the curved hooks, developed on stalk of the flowers fix the plants

to the neighbouring trees. *Sheakul*, *baganbilas* catch hold of their supports and remain attached by the spiny structures. (See fig. 42).

B. There are some climbers called **twiners** or **twining plants** which do not develop on them any special climbing organs. The stems themselves turn or coil around their neighbouring supports, as in *aparajita*, *shim*, *barbati*, *swarnalata*, etc. Most of them twine round their supports from left to right when they are called **sinistrorse.** Very few of them, such as *chupri-aloo*, *samudra shok* etc., however, coil from right to left. They are called **dextrorse**.

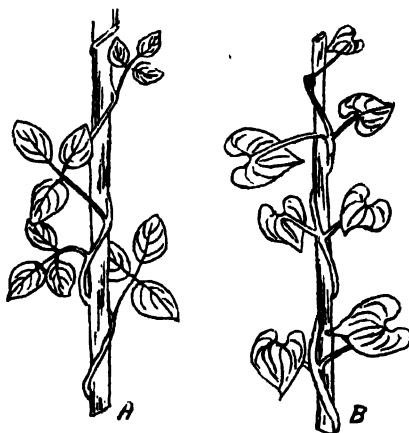


Fig. 43.
Twiners. A—Sinistrorse twiner of *shim*. B—Dextrorse twiner of *chupri-alu*.

Lianes are hard and thickened climbing plants which grow abundantly in tropical forests. *Madhobilata*, *Malati-lata*, *gulwncha* are climbers of this type with rope-like stems.

Trailers or Creeping stems

Like climbers these plants are also weak and slender and they can take their stand with great difficulty. They do not require any support against which they can lean. Thus unsupported, they grow above or along the surface of the soil. Sometimes they are prostrate and grow on the soil when no roots are developed from their nodes as in *puin*. In other cases during their growth roots are given off at the nodes. The ends of their stems tend to grow upwards. They are of the following forms :--

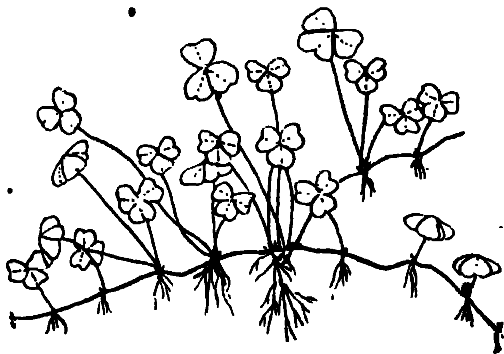


Fig. 44.

Runner of *amrul*.

(1) **Runner** or **stolon** grows as a long, slender and prostrate branch which arises from the aerial part of the parent stem or a little above the soil, but soon it bends down to come in contact with the soil where it produces new roots downwards and a new shoot upwards. A new plant can thus be formed at the end which now grows independently even if the branch is disconnected from the mother plant. It produces

branches in the same way to develop at its end another new plant and so on. Runners sometimes possess scaly leaves on them. They multiply vegetatively. The common runners are *amrul*, *kalmi*, *ghas* (creeping type), *latakochoo*, etc. Gardeners produce artificially new plants in some cases by pressing down branches into the soil as in *nebu*.

(2) **Offset** is also a stolon but its branch is a little shorter and thicker than the runner. The new plants formed at the ends bear tufts of leaves as found in *topa-pana*, *kachuri-pana* etc.

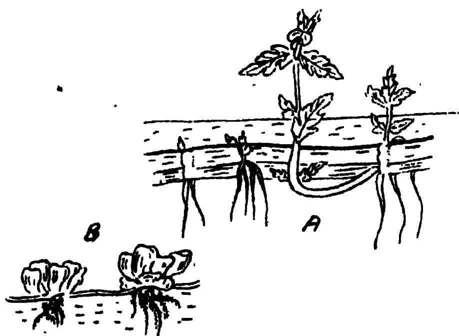


Fig. 45.

A—Sucker of *chandra mallika*. B—Offset of *topapana*.

(3) **Sucker** is an underground branch which growing horizontally below the soil for a short distance, rises up in the air giving off roots and a shoot to form an independent plant. The new plant in its turn produces an underground branch to grow in the same way. Some of the well known suckers are found in several garden plants, as, *chandra-mallika*, *bela*, *golap*, *pudina*, etc.

Sucker differs from stolon in this that in the former, the branches formed, are underground and they originate from underground stems, whereas, in the latter, both the branches as well as their points of origin are aerial.

Erect stems

There are many plants the stems of which are sufficiently strong to be able to grow in an upright position. These are called erect. They may be of the following forms :—



Fig. 46.
Strong stems.

(1) **Deliquescent**—When the tree is usually branched in a cymose manner, it becomes more or less rounded or dome-shaped. This is found in *deshibadam*, *bot*, *shiris* and may other plants.

(2) **Excurrent**—when the branching is racemose so that the branches are arranged in acropetal succession, the whole figure of the tree is like a pyramid in shape. The axis prolongs its growth upwards in a straight line throwing off many side-branches from base to apex, as *pine*, *debdaru*

(3) **Caudex**—This is applied to plants as *narikel*, *tal*, etc. which are usually unbranched and bear many scars of dead leaves on the surface of the uniformly cylindrical stems.

(4) **Culm**—This is applied to plants as *ak*, *bans*, *bhutta*, etc., which have their stems provided with distinct jointed nodes. Excepting a few plants, their internodes are hollow.

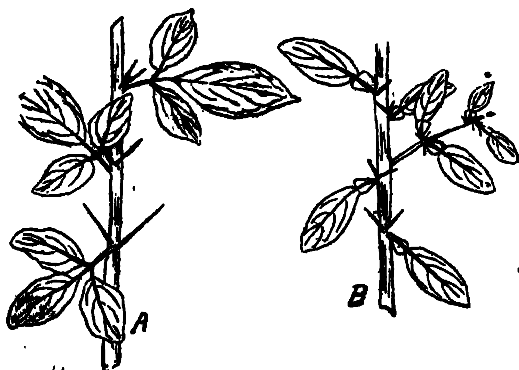


Fig. 47.
Thorns as modified branches.
A—*Bel* branch. B—*Nebu* branch.

Modified stems

Stems undergo modifications to serve special functions. They may be recognised as stem-structures by their mode of origin. Whatever be their forms, they originate from the axils of leaves. The following are chief forms :—

(1) **Thorns** are the modified branches or stems ; so they may bear branches or leaves on them. They can easily be distinguished from other similar outgrowths, as, spines, prickles, etc., by their position in the axils of leaves and by

their internal structure and connection with the internal parts of the stem. They must not be confused with spines which are modified leaves at the axils of which buds develop. The thorns of *bel*, *moynakanta*, *nebu*, *ankar-kanta*, etc. are all meant for protection.

(2) **Stem-tendrils** are leafless and coiling modified branches which are used as organs for climbing upon



Fig. 48.
Tendrils of *jhumkolata* as modified branches.



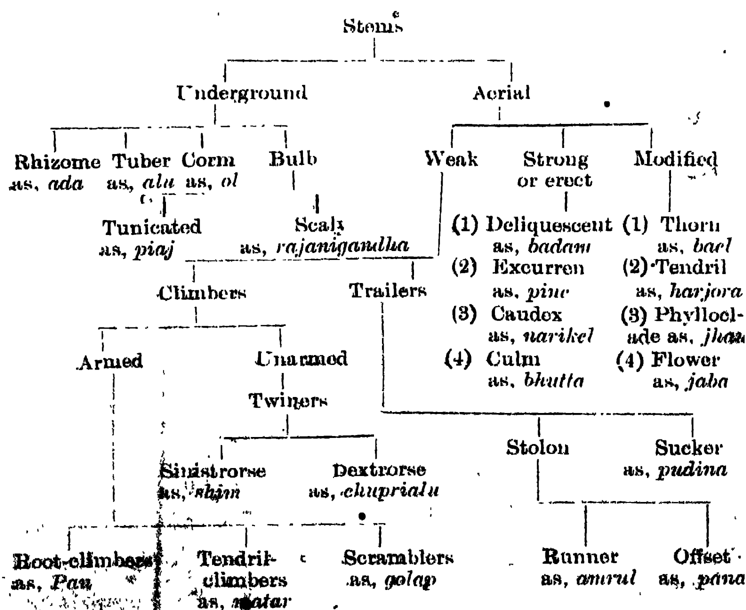
Fig. 49.
Phylloclade of *phanimansha*.

supports (vide page 57). They may be simple or branched. During growth, they catch hold of suitable objects, or in some cases, loose bodies round which they begin to coil. *Jhumkolata*, *goalelata*, *harjora*, etc. climb by means of the leaf-opposed tendrils

(3) **Phylloclades or cladodes** are modified green stems which may be flat or angular. The leaves on them are usually transformed into spines, as in *phanimansha*, *sij*, etc., or in some cases into minute scales, as in *jhau*. The functions of the leaves are performed by the stems. They usually grow in dry situations where they secure with great difficulty their food solution. (See Fig. 49).

(4) Flowers are also modified branches. The reasons, for taking them as branches, will be explained later on.

Tabular list of the different forms of stems.



Exercise IV

1. Describe the structure of a leaf-bud. Give an account of the different ways in which buds are protected.- C. U. 1929, 1922.

(Hint :—For protection, see how dormant buds are protected, page 44).

2. What is a branch ? Describe the main types of branching.—C. U. 1932.

3. How can you distinguish a stem from a root ? Describe their peculiarities as regards (a) the naked eye appearance (b) the branching, (c) the structure of the growing point.– C. U. 1926, 1914.

(Hint :—(c) the root-apex is covered with a root-cap but the stem-apex has a bud).

4. Name and describe the various kinds of underground stems. Why are they not regarded as roots ?—C. U. 1929, 1915, 1909.

5. How would you distinguish between a tuber, a rhizome, a corm a root-stock and a napiform root ? Describe and draw an example of each.— C. U. 1933, 1924, 1923.

6. Is a radish, a potato, an onion, or the corm, a stem structure or a root ? Give reasons.—C. U. 1926

7. Give an account of the various forms of the stem.—C. U. 1925.

8. Describe the modified forms of the stem for vegetative propagation. Give an example in each case with neat sketches.—C. U. 1932.

(Hint :—Describe the types of underground stems as well as runner, offset and sucker).

9. Give an account of the various ways in which climbing plants attach themselves to their supports.—C. U. 1925, 1912.

10. Define the terms citing examples - tunicated bulb, dichotomous branching, deliquescent, excurrent, caudex, stolon, cladode, tendril, scape, tubers.—C. U. 1926, 1923, 1921, 1917.

CHAPTER V

LEAVES

/ Leaves are laterally developed, dissimilar member appearing on stems or branches in acropetal order o succession and subtending buds in thei axils. The are exogenous outgrowths o the stem.) By leaves we commonly under stand the green flat bodies known a **foliage leaves.** Besides these leaves there are other types which hav different forms and structures i consequence of the diversity of function carried on by them. They are of th following types :—

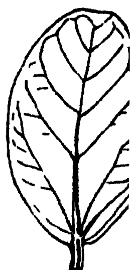


Fig. 50
Bot leaf

(a) **Seed leaves** or **cotyledons**—They are found in seeds.

(b) **Scaly leaves**—They are chiefly found in underground stems, when they are not green in colour. They protect the buds situated at their axils. In bulbs, they are also the store-houses of food matters. The scale leaves may also be found in dormant buds which they protect from the disturbances of weather, as *bans*, *magnolia*. They also occur in some aerial stems, e. g. *pine*, *jhau*, *satamuli*, etc.

(c) **Bract leaves**—They may be of several forms, usually subtending flower-buds at their axils. They may be green or of other colour, as in *basak*, *kala*, *baganbilas*, etc.

(d) **Floral leaves**—They occur in flowers and their main function is reproductive, directly or indirectly. They help the formation of seeds which is the goal of plant-lives. In flowering plants, the spore-bearing floral leaves and in pteridophytes all spore-bearing leaves are called **sporophylls**.

Functions of foliage or ordinary green leaves :—

(1) **Assimilation**.—The green leaves absorb carbon dioxide from air and manufacture carbonaceous food from the absorbed gas along with the water present in the leaves. This takes place in the presence of sunlight and through the help of green colouring matters of the leaves.

(2) **Respiration**.—The leaves absorb oxygen and give out carbon dioxide in connection with breathing.

(3) **Transpiration**—They give out water in the form of vapour specially in the day time.

(4) **Protection of buds** situated at the axils.

Other functions will be dealt with later in connection with the modifications of foliage leaves.

Parts of a leaf

There are three distinct regions of a typical foliage leaf :—

(1) **Leaf-base** or the basal region by which the leaf is attached to the stem.

(2) **Leaf-stalk** or **petiole** which joins the base with the upper portion of the leaf.

(3) **Leaf-blade** or **lamina** which usually forms the flattened portion of the leaf.

LEAF-BASE

By leaf-base the leaf is articulated to the stem. It has various forms. It is called **pulvinus** when it is swollen and cushion-like, as in the leaves of *am*, *krishnakali*, and all leaves of *matar* family, such as, *shim*, *babla*, *kalkasunda*, etc. When it forms a winged sheath embracing the stem wholly, or partially it is called **amplexicaul** or **semi-amplexicaul.** This is found in the leaves of *narikel*, *supari*, etc. and many leaves of *mouri* family.

Stipules

In many plants, it is noticed that the leaf-base has a pair of outgrowths arising from its two sides. They are known as **stipules.** The outgrowths remain separate or fused. They vary much in size, form and colour. When small and membranous, they appear functionless. They may remain attached to the plant as long as the leaves are present, but in many plants, such as *bot*, *kantal*, *kalkasunda*, etc., they are **deciduous**, i.e. they fall off soon after the expansion of leaves.

A leaf is called **stipulate**, when the stipules develop ; but when the stipules are absent, the leaves are **ex-stipulate**, as, *tulshi*, *dhutra*. Many Dicot leaves are stipulate but Monocot leaves are usually ex-stipulate. In *kumarika*, a Monocot, the leaf-base bears a pair of coiling outgrowths which are regarded as stipules.

Forms of Stipules.

(1) **Free lateral**, as in *jaba*, *bak*, etc., when they arise as two separate linear outgrowths on the two sides of the leaf-base.

(2) **Adnate**, as in *golap*, when the wing-like outgrowths on the two sides of the leaf-base run up to a certain distance of the petiole.

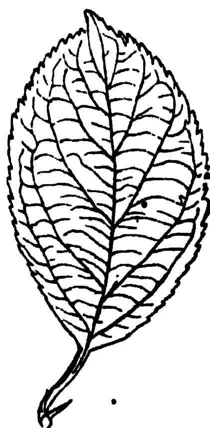


Fig. 51.
Free lateral stipules of *jaba*.

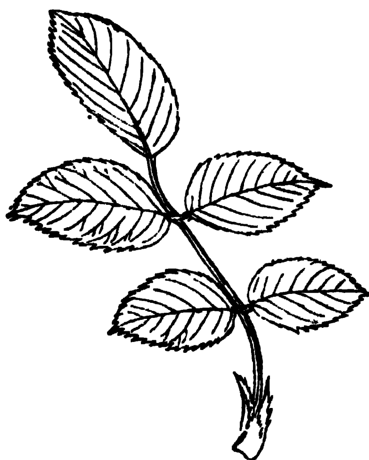


Fig. 52.
Adnate stipules of *golap*.

(3) **Foliaceous** or **leaf-like**, as in *matar*, *jangli-matar*, etc., when they become large and green in order to perform functions like those of green leaves. In *jangli-matar*, the leaf-blade is totally reduced to a tendril, so the stipules here act wholly as leaves. (See Fig. 41).

(4) **Inter-petiolar**, as found in most of the leaves of *rangan* family, as, *khetpapra*, *kadamba* etc. The leaves arise two at a time from each node and the stipules lie between the petioles of these two opposite leaves. The four stipules of the two leaves cohere to form two stipules, one on each side of the stem.

(5) **Ochreate**, as found in all the leaves of *panmarich* family, as, *chukapalang*, *ban-palang*, etc. The stipules form a tubular sheath or **ochrea** enclosing the internode up to a certain distance above the insertion of the leaf.



Fig. 53.

Stipules. a—Inter-petiolar stipule of *rangan*. b—Ochreate stipule of *panmarich*. c—Convolute stipule of *kantal*.

(6) **Convolute** stipules or **bud-scales**, as found in *bot*, *kantal*, *aswatha*, etc. They cover and protect young shoots and fall off when the leaves of the shoots begin their development.

(7) **Spiny**, as found in *babla*, *lajjabati*, *Kantagur-kamai*, etc., when the stipules are modified in the form of spines for protection against the attacks of animals.

(8) **Tendrillar**, as in *kumarika*, when they are transformed into tendrils for the purpose of helping the

plants in climbing and thus in attaching themselves to their supports.

Functions of Stipules.

(1) Mainly they protect buds along with the leaf-base as, in *jaba*, *bak*. But, in *kantal*, they protect the whole of the growing shoot.

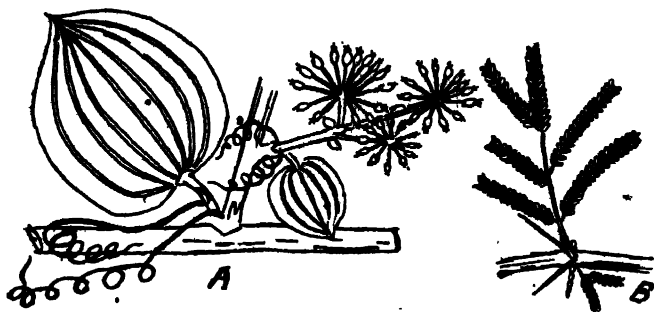


Fig. 54.
Modified stipules. A – Tendrillar stipule of *kumarika*.
B – Spiny stipule of *babla*.

(2) In *matar*, *jangli matar*, they are assimilatory, i. e., act as green leaves.

(3) In *babla*, they protect the plants from the attacks of animals.

(4) In *kumarika*, they help the plants in climbing.

LEAF-STALK

When the leaves are stalked, they are called **petiolate** ; but they are **sessile** when no stalk is present as, *rangan*, *akanda*, etc.

The main object of the development of petiole is to enable the lamina to expose itself to suitable illumination. Petiole may be winged, as in *kamala-nebu*, *nebu*, *batabi-nebu* ; cylindrical, as in *jaba* ; flat, as in *mula* ; hollow, as in *kumra* ; swollen, for storing air to enable plants to float on water, as in *kachuripana*, *singara*, etc. Petiole, when prolonged, is continuous with the midrib of the lamina and



Fig. 55.
Modified petioles. A, A′ Ligulate leaves of *ghas*. B—Phyllode of Acacia. a—Ligule. b - Petiole. c—Leaf-blade.

is thus placed at its base. But in *padma*, *kumud*, *kochoo*, etc. the petiole is attached about the middle of the under surface of the lamina. These are called **peltate** leaves.

In some Acacias, the leaf-blade falls off during growth and in order to serve the functions of the absent blade,

petiole becomes expanded and leaf-like in form. This is called **phyllode**. In *akasmoni*, one of the Acacias, usually planted on the road-side of Calcutta, the leaf-blade is entirely absent.

The leaves of *ghas*, *dhan*, *ak*, etc., have sheathing bases. The sheath, which surrounds the stem for some distance, bears a few hairy structures, called **ligules**, at the junction of the blade and the base. Such leaves are called **ligulate**. The hairs serve to prevent raindrops from entering into the sheath.

LEAF-BLADE

This is the main part of a leaf with which the functions of leaves are concerned. This is placed at the end of the stalk so that it can adjust its position in connection with light it is to receive for performing its functions. In studying the blade, the following points are to be considered :—

(1) **Venation**. (2) **Apex**. (3) **Margin**. (4) **Shape**. (5) **Incision**.

Venation.

The fine thread-like structures which start from the end of the petiole and pass through the leaf-lamina are known as **veins**. They are distinctly seen when any thin leaf is held against the sun-light. They are distributed throughout the lamina in order to strengthen it and to protect it from the mechanical disturbances of weather.

Each **vein or vascular bundle** consists of two parts, one of which is concerned in the conduction of raw food materials from soil while the other is to distribute the food, manufactured in the leaves, to the different parts of plants. The vascular bundles, present in the stems and roots, are continuous with those of the leaves.

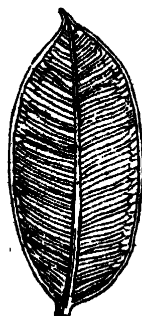


Fig. 56.
Veins of *jam* leaf.

The arrangement and distribution of these veins in the different parts of the blade are known as **Venation.**

The two chief types of venation found in all Dicot and Monocot leaves are (1) **Reticulate** and (2) **Parallel.**

The venation is **reticulate**, when the prominent veins, with their branches and sub-branches, traverse the whole lamina so as to form a network. This is found in the leaves of *jaba*, *bot*, *padma*, etc. This is the **characteristic venation of all Dicot leaves** and a few Monocot leaves as, *kochu*, *ol* etc.

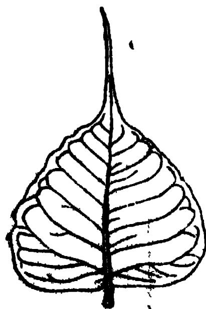


Fig. 57.
Leaf of *aswatha*.

When the veins, large or small, starting from the end of the petiole pass through the whole length of the lamina in such a way that they are more or less parallel to one another, the venation is **parallel**. This is the **characteristic venation of most of the Monocot leaves. The venation is one of the main points by which the Dicots are distinguished from the Monocots.**

Both these two above types may be **pinnate** or **unicostate,** and **palmate** or **multicostate**. They are **pinnate,** when there is only one prominent vein, in the leaf, called **midrib,** from which branches develop and pass through the lamina. This is found in the leaves of *am*, *kantal*, *bot* etc. When several prominent veins arise at a time from the same point at the end of the petiole and

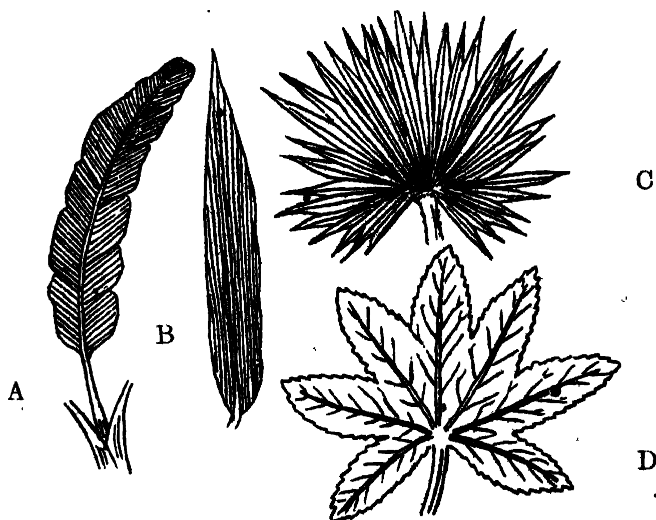


Fig 58.

Leaf venation. A—Parallel venation of *kala* leaf. B—Parallel venation of *bans* leaf. C—Divergent venation of *tal* leaf. D—Venation of *rerhi* leaf.

when they go on diverging from one another to reach the end of the blade, the venation is **palmate**, as found in the leaves of *pepya*, *rerhi*, *padma*, etc.

In palmate venation the prominent veins may be **convergent**, when they meet towards the apex or margin of a leaf. They may be **divergent**, when they diverge so that they have no chance of meeting afterwards in the leaf, as many *palms*, *padma*, etc. Divergent leaves are more common than convergent ones.

Thus we find in the summary, the following types of venation in the different leaves :—

(a) **Reticulate pinnate,** as in *am.*

(b) **Reticulate palmate convergent**, as in *tejpat, kumarika.*

(c) **Reticulate palmate divergent**, as in *padma.*

(d) **Parallel pinnate,** as in *kola.*

(e) **Parallel palmate convergent,** as in *ghas.*

(f) **Parallel palmate divergent** as in *tal.*

Apex

Apex of leaves may be as follows :—

(1) **Acuminate** i. e., the end drawn out to a long fine point, as in *aswatha.*

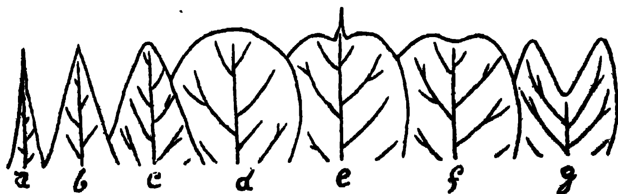


Fig. 59.

Different types of leaf-apex. a –Acuminate. b—Acute. c—Obtuse. d—Truncate. e—Mucronate. f Retuse. g—Emarginate.

(2) **Acute**, i.e., ending in an acute angle, as in *jaba, am.*

(3) **Obtuse**, i.e., with a blunt head, as in *badam, beli.*

(4) **Truncate**, i. e. ending in a flat line as if the leaf has been cut across in its head, as in some *palms*.

(5) **Mucronate**, i. e. ending in a sharp point, as in *nayantara, ranjan*.

(6) **Retuse**, i.e., ending with a slight depression in the middle. as in *aparajita*.

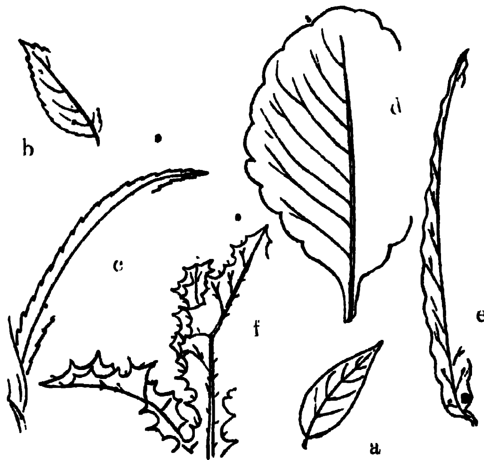


Fig. 60.

Different types of leaf-margin. a—Entire. b—Serrate. c—Dentate. d—Crenate. e—Wavy. f—Spiny.

(7) **Emarginate,** i.e., ending with a deep depression in the middle, as in *kanchan*, *amrool*.

(8) **Tendrillar,** i. e., ending in a tendril, as in *ulätchandal*.

(9) **Spiny,** i.e., ending in spines, as in *khejur*, *anaras*.

Margin

Margin may be as follows :—

(1) **Entire**, i. e., with no projections, as in *aswatha*, *bot*.
(2) **Serrate**, i.e., with projections like the teeth of a saw, as in *jaba*, *golap*.
(3) **Dentate**, i.e., with teeth-like projections at right angles to the margin, as in *waterlily*.
(4) **Crenate**, i. e., with round projections, as in *patharkuchi*.
(5) **Wavy**, i.e., with undulating margin, as in *debdaru*.
(6) **Spiny**, i.e., with sharp projections, as in *shealkanta*, *kantikari*.

Shape

Shape of the leaves may be of the following types :—

(1) **Acicular**, i.e., needle-shaped, as in *pine*.
(2) **Linear**, i.e., long and narrow with margins more or less parallel, as in *dhan*, *ghas*.
(3) **Lanceolate**, i.e., lance-shaped or much longer than broad and tapering at the base and apex, as in *debdaru*.
(4) **Elliptical**, i.e., not so long as lanceolate but broad, as in *karamcha*, *tagar*.
(5) **Oblong**, i.e., rounded at the base as well as at the apex, as in *tentul*, *babla*.
(6) **Ovate**, i.e., broad at the base but narrow at the apex, as in *jaba*, *aswatha*.

(7) **Ob-ovate,** i.e., inversely ovate, as in *badam*, *kantal.*

(8) **Cordate,** i.e., heart-shaped or with two broad lobes at the base and narrow above, as in *pah*, *choi*, *chupri-aloo.*



Fig. 61.

Different forms of leaves. a—Acicular. b—Linear. c—Lanceolate. d—Oblong. e—Ovate. f—Cordate. g Ob-cordate. h—Sagittate. i—Hastate. j—Reniform. k—Orbicular. l—Auriculate.

(9) **Ob-cordate,** i. e., inversely cordate, as *kanchan*, *amrool.*

(10) **Sagittate,** i.e., arrow-shaped, as in *kochoo.*

(11) **Hastate,** i.e., with two lobes at the base at right angles to the axis of the leaf, as in *kalmi*, *panphal*.

(12) **Reniform,** i.e., kidney-shaped, as in *thankuni*.

(13) **Orbicular,** i.e., circular, as in *padma*.

(14) **Auriculate,** i.e., with two ear-like projections at the base, as in *akanda*.

Incision or lobation

When the lamina is incised or segmented from the margin, the leaf is said to be **lobed**, and the segments, thus produced as the result of incision, are called **lobes**.



Fig. 62.
Segmented pinnate simple leaves, A, B, C compared with a compound pinnate leaf.
A—Pinnati-fid. B—Pinnati-partite. C—Pinnati-sect

In a **pinnate** leaf, if the segmentations do not pass half way down the midrib, the leaf is **pinnatifid**; if more than

half way, it is **pinnati-partite** ; but if they pass nearly to reach the midrib, it is **pinnati-sect**. Examples of leaves with these three types (**fid, partite** and **sect**) of lobations or segmentations can be found in *chandramallika*, *tarulata*, *genda*, etc.

Similarly when the leaves are **palmate** in venation they may be **palmati-fid, palmati-partite** or **palmati-sect,**



Fig. 63.
Segmented palmate simple leaves, A, B, C, compared with compound palmate leaf, D. A—Palmati-fid. B—Palmati-partite. C—Palmati-sect.

when their lobations show the above three types viz., fid, partite and sect. The palmate leaves of *pepya*, *rerhi*,

bharenda, *bhumi-kumro*, *kapas*, etc. with their varying depths of incision are good examples.

In some cases, incisions are not so regularly observed as in the above cases. Thus, in *phulkapi*, *mula*, etc., the pinnate leaves are incised in such a way that there is a large round lobe at the head, while the lower lobes are gradually smaller and smaller. Such leaves are called **lyrate**.

SIMPLE AND COMPOUND LEAVES

A leaf is said to be **simple** when there is a single blade. A leaf is said to be **compound** when there are two or more distinct blades all articulated to a common stalk, axis or branches thereof.

In the case of a simple leaf, the blade is not divided into separate parts, however deeply it may be incised, but if the blade is divided into distinct separate parts, the leaf is called **compound**, and the separate parts are called **leaflets**. The leaflets may be arranged oppositely on the mid-rib or may radiate from the same point of the petiole-end.

In studying incision, we have noticed that though there are the gradations of incision in pinnate or palmate leaves, they are always simple but when the incision extends right upto their mid-rib or the base of the lamina, the leaves are divided or incised completely and then they become compound with the divided parts as leaflets.

In most cases, the leaflets resemble simple leaves in their apex, margin, shape, and arrangement of veins in them. They differ from simple leaves in having no bud at their axils. The bud is present at the axil of the compound leaf but never at the axils of the leaflets.

The stipules may be present at the base of simple leaves. Compound leaves, when stipulate, have the stipules developed at their base. These stipules are found in *bok*, *krishna-chura*, etc. Sometimes, stipule-like out-growths appear at the base of the leaflets, when they are called **stipels**, as found in the leaflets of *aparajita*, *kal-kashunda*, etc.

Compound leaves and a branch with simple opposite leaves compared

Compound leaves are often mistaken for a branch bearing simple leaves which are arranged oppositely, as in *lichoo*. Similarly a branch, with simple opposite leaves, may be mistaken for a compound leaf, as in *amloki*, *nole*, *bhumi-amla*, etc. The main difference between them lies in the fact that the **branch has a bud at its apex which helps its upward development** but in the case of a compound leaf no such bud or growing point lies at the head, so there is no further upward development of the axis of the leaf. Moreover, **the branch bears no bud at its base** but the compound leaf possesses always an axillary bud. The **leaves on the branch have buds at their axils** which the leaflets of the compound leaf do not possess.

Types of Compound leaves

As in simple leaves, the compound leaves may be either **pinnately** or **palmately veined.**

(1) **Pinnately compound leaves** are those in which the leaflets are all arranged on the two sides of the common axis or mid-rib which is a direct prolongation of the petiole, as in *nim*, *asoka*, *aparajita*, *matar*, etc.



Fig. 64.
Imparipinnate compound leaf of *matar*

These leaves may be **paripinnate**, when all the leaflets are paired, i.e., the number of leaflets on the two sides of the mid-rib is even, as in *kalkashinda*, *tentul*, etc. They may be **imparipinnate** when, besides the paired leaflets, there is an additional terminal leaflet or the number of leaflets on the mid-rib is odd, as in *kamini*, *beli*, *golap*, etc.

When the leaflets are on the first set of branches of the common axis, leaves are called **bipinnate**, as in *babla*, *krishna-chura*. When the leaflets are on the second set of branches, leaves are **tripinnate**, as in *sajina*. The leaves are **decompound** when the divisions of the axis occur again and again, as in *mouri*, *dhania*, etc.

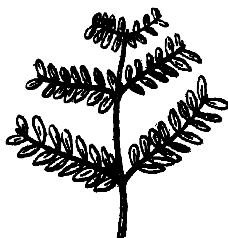


Fig. 65.
Bipinnate leaf of *krishna-chura*

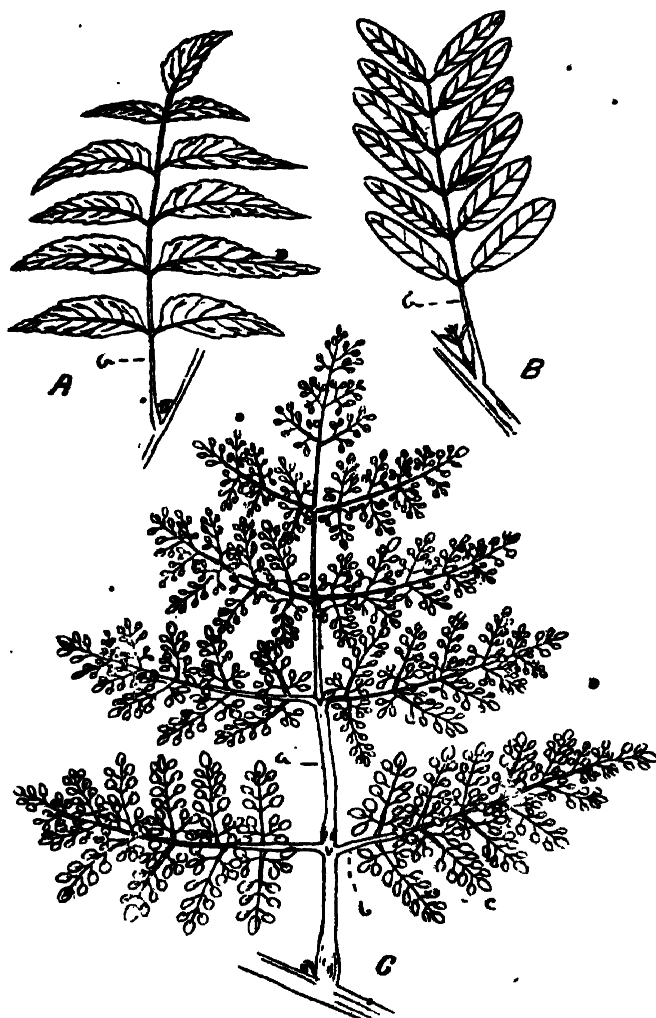


Fig. 66.

A—Imparipinnate leaf of *nim*. B – Paripinnate leaf of *kalkasunda*. C—Tripinnate leaf of *sajina*. a—Mid-rib. b—First set of branches of the mid-rib. c—Branches of b.

(2) **Palmately compound leaves** are those in which all the leaflets arise from the same point at the end of the common axis, as in *simul*. According to the number of leaflets arising from the axis, the leaves may be **unifoliate**, as *nebu*; **bifoliate**, with two leaflets; **trifoliate** or **ternate**, with three leaflets, as *bel*, *amrul*; **quadrifoliate**, with four leaf-



Fig. 67.
Palmately compound leaves. A Trifoliate leaf of *amrool*. B—Trifoliate leaf of *bel*. C—Quadrifoliate leaf of *shusnishak*. D—Biternate leaf.

lets, as *shushni shak* and so on. In *nebu*, the single leaflet is distinctly articulated with the winged petiole at its base. **Biternate leaf** is one when the leaflets of the trifoliate type are again compounded, i.e., each of the three petioles produces in its turn three leaflets at a time from the same point, as in *bel* leaves in the upper branches of the tree.

When the axis branches palmately and on each of the branches leaflets are arranged pinnately, the leaves are called **digitately pinnate,** as in *lajjabati.*

Leaves modified for special functions.

(1) The leaf-blade may be extremely reduced to form a **spine**. This is to protect plants from the attacks of animals. Spiny character of leaves is found in plants

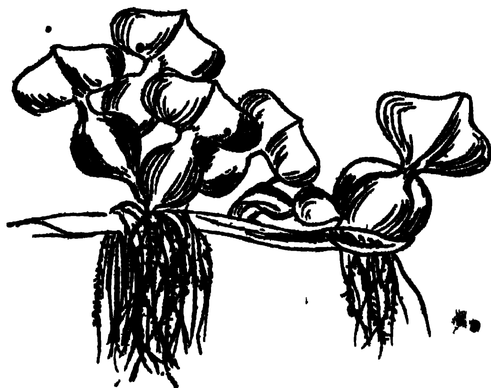


Fig. 68.
Kachuri pana with bladder-like petioles.

growing in hot and sandy situations where reduction of the leaf-surface is necessary, as in *phani mansha, manshashij, shealkanta,* etc.

(2) For diminishing transpiration, i. e., removal of surplus water from the plant system, leaves may be **needle-shaped,** as in *pine,* or covered with **hairs,** as in *ghas, dhan,* or coated with **waxy secretion,** as in *akanda.*

(3) Leaf-blade may be transformed wholly or partly into a **tendril** for the climbing purpose. The apex of the *ulat-chandal* leaf or the upper leaflets of *matar* are tendrillar. The stipules of *kumarika* are, as we have seen before, modified into tendrils for the same purpose. The whole leaf, converted into a tendril, is seen in *jangli-matar* where the green expanded stipules serve the functions of leaves. Here the tendrils are not only the climbing organs but also diminish transpiration.

(4). The leaves of water plants, when floating, may possess swollen **bladder-like petioles** which help the leaves as well as the plants to float. This device is observed in the leaves of *kachuri-pana*. These submerged leaves of water-plants are usually much **dissected**, as in *singara*, *jhangi*, or long **ribbon-shaped**, as in *pata shaola*. Thus, offering less resistance to the currents of water in which the plants grow, they preserve their leaves from mechanical injury.

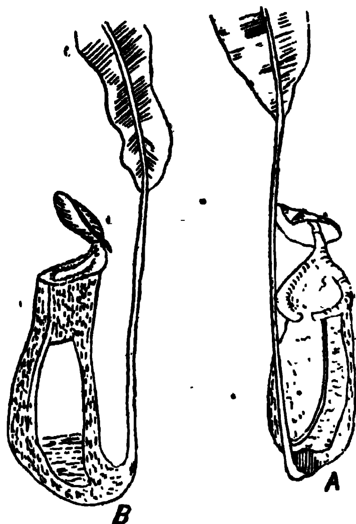


Fig. 69.
Pitcher-plant leaves.

(5) Some **fleshy** leaves as of *ghrita-kumari*, *pathar-kuchi*, make provision for the storage of food and water for future use. For the same reason, the inner leaves of the bulb of *piaj* are fleshy.

(6) Leaves of insectivorous plants are modified into **pitcher-like** structures as in *pitcher plant*; **bladder-like** bodies as in *bladder wort*. These modifications, as we know them before, are for alluring and entrapping insects from which they obtain nitrogenous food when they are decomposed within their leaves.

PREFOLIATION

Prefoliation indicates the mode of arrangement of young leaves in the bud. This can be considered under two heads :—

(1) **Ptyxis** is the arrangement of individual leaves or the way in which each leaf is arranged in itself.

(2) **Vernation** is the arrangement of different leaves in the bud, in relation to one another. This arrangement is clearly understood on taking a cross section of the bud.

N. B. There is some controversy over the use of above two terms. Some include ptyxis in vernation, while others use them separately. There are others who use only vernation.

Ptyxis may be **folded** or **rolled**.

Folded ptyxis occurs in the following types :—

1. **Conduplicate**, when one half of the lamina folds longitudinally over the other, as in *kanchan*, *peyara*, etc.

2. **Plicate**, when there are many longitudinal foldings of the lamina, as in *tal*.

3. **Reclinate**, when the upper half folds over the lower, as in *patabahar*.

4. **Crumpled**, when the foldings are irregular and in all directions, as in *bandha kopi*.

Rolled ptyxis occurs in the following types :—

1. **Circinate**, when the lamina is rolled from the apex to the base like a dog-tail as, in *ferns*.

2. **Convolute**, when the lamina is rolled from one margin to the other, as in *Kola, swarba-jaya*.

3. **Involute**, when the lamina is rolled from both the margins towards the mid-rib on the upper side, as in *padma, kochu, saluk*.

4. **Revolute**, when the lamina is rolled, as in the case of invoulute, but the rolling is on the lower side, as in *karabi, gandharaj*.

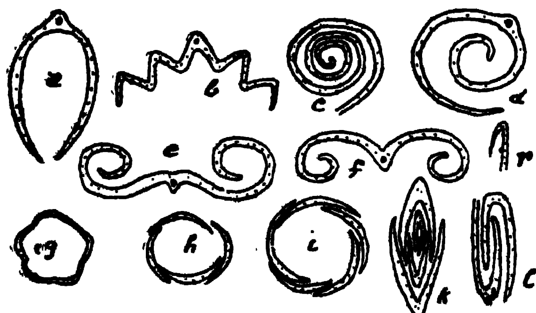


Fig. 70.

Ptyxis and vernation of leaves. a—Conduplicate. b—Plicate. c—Circinate. d—Convolute. e—Involute. f—Revolute. g—Valvate. h—Imbricate. i—Twisted. k—Equitant. l—Half-equitant. r—Reclinate.

(2) Vernation occurs in the following ways :—

1. **Valvate**, when the margins of the leaves in the bud touch each other but do not overlap.

2. **Imbricate**, when the margins of the leaves overlap.

3. **Twisted** or **contorted**, when one margin of each leaf is placed inwards and is thus overlapped while the other margin is placed outwards and thus overlap the margin of the neighbouring leaf.

4. **Equitant**, when the margins of one conduplicate leaf are within those of another, as in *dashbaichandi*.

5. **Half-equitant**, when one margin of a conduplicate leaf is placed within the margin of a neighbouring conduplicate leaf, as in some kinds of *ghas*.

These terms are generally applied to the arrangements of floral leaves which will be dealt with later.

PHYLLOTAXIS

Phyllotaxis is the way in which leaves are arranged on the stems or branches. There are certain laws which govern this arrangement or distribution of leaves. It varies in different kinds of plants.



Fig. 71.
Alternate phyllotaxis of a *bot* shoot.

The significance of phyllotaxis is that the leaves are placed on the different regions of stems or branches in such a way, that they can enjoy the sunlight as fully as possible in order to perform their functions which are always impossible without light.

There are three kinds of phyllotaxis :—

(1) **Alternate,** in which a single leaf arises at a node. as in *bot*.

(2) **Opposite,** in which two leaves arise at a time from a single node, as in *tulsi*.

(3) **Whorled,** in which more than two leaves arise at a time from a single node, as in *karabi*.



Fig. 72.

Whorled phyllotaxis of *karabi* leaves.

Alternate or spiral phyllotaxis.

This is also called **scattered** as leaves seem to be arranged scatteredly though, really there are some laws which control the phyllotaxis. The following **laws** seem to be very interesting to follow :—

(a) All the leaves are never on one side of the stem.

(b) An imaginary line, connecting the successive leaf-bases, becomes continuous and winds symmetrically upwards round the stem, like the threads of a screw. This is called **genetic spiral**.

(c) When several imaginary vertical lines called **orthostichies** are drawn on the stem passing through the leaf-base, all the leaves on the stem are found to lie on those lines. According to the number of orthostichies on the stem, the arrangement may be **distichous**, when two; **tristichous**, when three, **pentastichous**, when five; **octostichous**, when eight and so on.

(d) The orthostichies are always equidistantly placed, i.e., they divide the circumference of the stem into as many parts as the number of orthostichies.

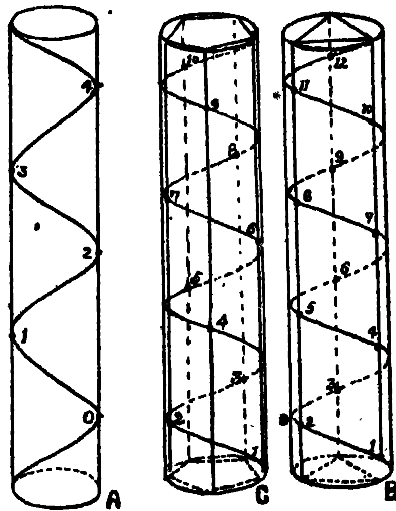


Fig. 73.

Orthostichies in alternate phyllotaxy. A—Distichous arrangement. B Tristichous arrangement. C—Pentastichous arrangement.

(e) The distance on the circumference of the stem between any two nearest leaves is known as **divergence**, or **circumferential distance**.

(f) The angle, subtended by the divergence at the centre of the stem, is called the **angle of divergence** or **angular divergence**.

Divergence may be determined practically by the fraction of the circumference of the stem, the numerator of which represents the number of turns the spiral travels starting from any leaf and then reaching another leaf vertically above the starting leaf, while the denominator represents the number of orthostichies on the stem. Angular divergence is measured in degrees and is equal to divergence of the entire angle at the centre. Thus, if n is the number of turns of the spiral, and o the number of orthostichies, then the angle of divergence is equal to n/o of 360°.

Thus in **distichous** arrangement, the odd number of leaves is placed on one orthostichy while the even number on another orthostichy. The divergence is ½ and the angle is ½ of 360° = 180°. This is found in the plants of *ghas* family as well as in *dulal champa*, *amloki*, etc.

In **tristichous** arrangement, the leaves numbered 1, 4, 7, 10, etc., are on one line, those numbered 2, 5, 8, 11 etc., are on the second, while those numbered 3, 6, 9, 12 etc. are on the third line. As the spiral, starting from the first leaf travels once round the stem to reach the fourth leaf which is vertically above the first leaf, the divergence is ⅓ and the angle is divergence ⅓ of 360°, i. e. 120° This is found in the plants of *mootha* family.

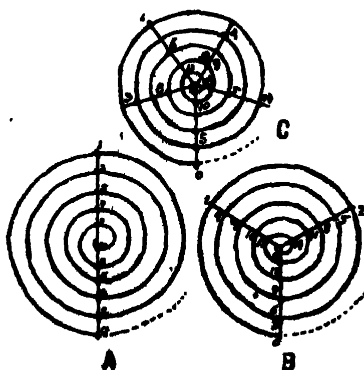


Fig. 74.
Phyllotaxy represented in circles.
A—½, B—⅓, C—⅖ arrangement.

In **penta-stichous** arrangement found in many Dicot plants, as, *jaba*, *dhanras*, *kapas*, *jeoli*, *sal*, etc., the leaves

are on five orthostichies. The spiral here travels twice round the stem, when it starts from the first leaf and reaches the sixth leaf vertically above the first leaf. Thus the divergence is $\frac{2}{5}$, and the angle is $\frac{2}{5}$ of 360°, i. e. 144°.

In the same way, in octostichous arrangement occurring in *pepya, apang, morogphul, etc.* the divergence is $\frac{3}{8}$, and the angle is 135°. The next higher ranks, found in plants, are $\frac{5}{13}$, $\frac{8}{21}$ etc.

In twining plants, as the orthostichies are not vertical but twisted, the phyllotaxis is then called **parastichous.**

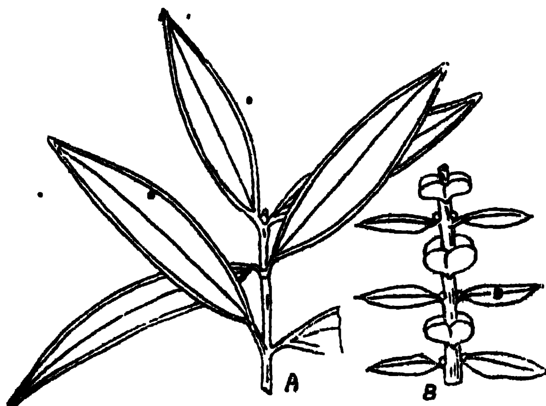


Fig 75.
Opposite phyllotaxy A and B – Decussate leaves showing different positions.

Opposite and whorled phyllotaxis.

There are two laws which govern the arrangement :—

(a) Whatever may be the number of leaves at each node on the stem, they will be placed at an equal distance from one another. Thus, when the number is two, they will

divide the circumference of the stem equally, and at each division they will be placed. This law is applicable to all leaves which are in the same node.

(b) Leaves of any node may be placed immediately above or below the gaps left between the leaves of the nodes next above or below. Thus when the leaves are opposite at any node, they stand at right angles to the next higher or lower pair of leaves. This arrangement, found in *akanda, tulsi* and *kalmegh* families, is called **decussation** and the leaves thus arranged are called **decussate**. All pairs of leaves of any two odd numbers of nodes are parallel to one another. Similarly, all pairs of any two even numbers are parallel. But when a pair of any odd number be compared with that of any even number, they are found to be at right angles to each other. This law, applicable to all opposite leaves of the different nodes, is also followed by the whorled leaves of *karabi*, *chhatim*, etc.

Opposite leaves, not arranged decussately, are sometimes placed on two vertical lines on the stem, so that the pairs are all parallel to one another. They are known as **superposed,** as found in *peyara, Rangoon creeper*, etc.

LEAF-MOSAIC

We find that in every plant, leaves are arranged on the stem following certain definite rules in order to prevent overlapping and to secure the maximum amount of light.

To secure further economy of space and materials and to utilise as much sun-light as possible, leaves of the same plant and even on the same branch may vary in their shapes and sizes so as to fit into each other without

overlapping like the bits of glass in a mosaic, to present a continuous leafy surface. This phenomenon is known as **leaf mosaic**. This is clearly observed in *krishnakali*, *amrool*, *jaba*, *toonth*, etc.

HOMOLOGY AND ANALOGY.

Having described the different members, as roots, stems and leaves, we are now to consider the similarity and dissimilarity of members. **Members, which are morphologically similar i.e., which are similar in their origin, position and development, are called homologous.** They may serve different functions, so they may be modified differently and thus assume different forms. In other words, homologous bodies are similar morphologically but may be different physiologically. Thus, tubers of *alu*, rhizomes of *halud*, bulbs of *piaj*, runners of *amrul*, thorns of *bel*, tendrils of *jhumkolata* and cladodes of *phanimansha* are homologous with **stems**, whatever be their forms. They are all **homologues** of each other, as they are of similar origin. Similarly, cotyledons, scaly leaves of underground stems, bracts, floral leaves, sporophylls of pteridophytes, spines of *phani-mansha*, tendrils of *mushurchana* and phyllodes are homologues of each other, as they are homologous with **leaves**.

On the other hand, **members which are similarly modified in their forms to perform similar functions but are different in their origin and development**, are called **analogous** or they are **analogues of each other**. Analogous members are physiologically similar though they differ morphologically. Thus the tendrils of *ulat-chandal*,

and those of *harjora* are not homologous but analogous ; the spines of *teshira-mansha* and thorns of *moynakanta* are analogous. In the same way, the tubers of *chupri-alu*, and those of *ranga-alu* are analogues of each other.

Summary of Chapter V

1. There are different types of leaves besides foliage leaves. (1) **Cotyledons**, (2) **Scale leaves**, (3) **Bract leaves**, and (4) **Floral leaves**.
2. The normal functions of leaves are (1) Protection of buds, (2) Assimilation, (3) Respiration, (4) Transpiration.
3. A leaf consists of (1) **leaf-base**, (2) **leaf-petiole** and (3) **leaf-lamina**.
4. Leaf-base may be **pulvinus**, **amplexicaul** or **semi-amplexicaul**.
5. **Stipules** are outgrowths at the base of a leaf. Leaves may be **stipulate** or **exstipulate**.
6. The forms of stipules are :—(1) **Free lateral**, (2) **adnate** (3) **Foliaceous**, (4) **Interpetiolar**, (5) **Ochreate** (6) **Convolute**, (7) **Spiny**, (8) **Tendrillar**.
7. Leaf is **sessile**, when the petiole is absent. When the blade is absent but the petiole is well-developed, it is **phyllode**. Petiole being fixed about the middle of the blade, the leaf is **peltate**. The leaf is **ligulate**, when hairs are developed at the junction of the blade and base.
8. **Venation** of leaves may be **parallel**, **reticulate**, **pinnate** and **palmate**.
9. **Apex** may be (1) **Acuminate**, (2) **Acute**, (3) **Obtuse**, (4) **Truncate**, (5) **Mucronate** (6) **Retuse**, (7) **Emarginate** (8) **Tendrillar**, (9) **Spiny**.
10. **Margin** may be (1) **Entire**, (2) **Serrate**, (3) **Dentate**, (4) **Crenate**, (5) **Spiny**.
11. **Shape** of the leaves may be (1) **Acicular**, (2) **Linear**, (3) **Lanceolate** (4) **Elliptical**, (5) **Oblong**, (6) **Ovate**, (7)

Obovate, (8) **Cordate,** (9) **Obcordate,** (10) **Sagittate,** (11) **Hastate,** (12) **Reniform,** (13) **Orbicular,** (14) **Auriculate.**

12. **Incision** may be **fid**, **partite**, and **sect**.

13. Leaves may be **simple** or **compound**. The blade of the simple leaf is not divided down to the mid-rib but that of the latter is cut up in separate or distinct parts called **leaflets**.

14. Compound leaves may be **pinnate** or **palmate**. Pinnate may be **paripinnate** or **imparipinnate**, **bipinnate** and **tripinnate**. Palmate may be **bifoliate**, **trifoliate,** etc.

15. Leaves may be modified into **tendrils**, **spines**, **dissected**, **ribbon-shaped**, **fleshy**, **bladder like**, **pitcher like,** etc.

16. **Ptyxis** is the arrangement of leaves in the bud This may be (1) **Conduplicate,** (2) **Plicate,** (3) **Crumpled,** (4) **Circinate,** (5) **Convolute**. (6) **Involute,** (7) **Revolute. Vernation** may be (1) **Valvate,** (2) **Imbricate,** (3) **Twisted,** (4) **Equitant,** (5) **Half-equitant.**

17. **Phyllotaxis** is the arrangement of leaves on stems. This may be **alternate, opposite** or **whorled**. The imaginary spiral connecting the leaf bases is the **genetic spiral.** The vertical lines on stems on which all leaves are placed, are **orthostichies. Divergence** is the distance between any two neighbouring orthostichies. **Angle of divergence** is the angle of the divergence at the centre. According to the number of orthostichies, alternate phyllotaxis may be **distichous, tristichous**, **pentastichous,** and so on. When the leaves are **opposite** and when the successive pairs are at right angles they are **decussate.** Leaves are **superposed** when they are opposite and on two lines.

18. **Leaf mosaic** expresses the variation of shapes of leaves when they are to catch scanty amount of light.

19. **Homology** expresses the resemblance existing between the plant-members agreeing in their origin and development, while **analogy** expresses the resemblance in their functions and forms.

Exercise V

1. What are the normal functions of leaves? For what other purposes leaves may be utilised? - C. U. 1917.

(**Hint** :— State other functions of leaves, page 87).

2. What are stipules and how may they be modified - C. U. 1929, 1909.

3. What is venation and what are its principal forms? What are the functions of the system of veins? Illustrate your answer with sketches. - C. U. 1926, 1918, 1911.

4. Give an account of the different forms of leaves, and the various types of apices in them—C. U. 1927.

5. Describe the different shapes of the lamina of leaf. Give examples - C. U. 1920.

6. Describe the various parts of a leaf and enumerate, with examples, the various modifications that leaves may undergo. — C. U. 1928, 1919, 1918.

7. Define a simple and a compound leaf. Clearly point out the main differences between the two. Describe the types of compound leaves and give examples. — C. U. 1932, 1924, 1922, 1919.

8. Distinguish between vernation and aestivation. Describe the principal forms of each. —C. U. 1933, 1929.

Hint :—Vernation is the arrangement of foliage leaves in the bud while aestivation is the arrangement of floral leaves in the bud. For the forms of aestivation consult the chapter on flowers.

9. Give a short account of the arrangements of the leaves on the stems and branches. What are leaf mosaics? —C. U. 1921, 1923, 1915, 1910.

(**Hint** :—For the first part, explain the different types of phyllotaxis).

10. Write short notes on :— mucronate leaves, pinnatifid, peltate leaves, ochreate and interpetiolar stipules, distichous phyllotaxy, pulvinus, amplexicaul, decussate leaves. — C. U. 1923, 1921, 1920, 1919.

CHAPTER VI

INFLORESCENCE AND BRACTS

Inflorescence

We have seen before that all flowering plants bear two different kinds of shoots, viz. **vegetative shoot** and **reproductive shoot**. When the vegetative organs of a plant are fully developed, the time now comes for the plant to serve the next most important function, i.e. reproduction. Reproductive organs develop in the forms of flowers which are specially modified shoots. The reproductive shoot may bear a single flower or may form a branch system bearing a large number of flowers. This branch system producing a cluster of flowers on it is known as **inflorescence**. It is thus a collection of flowers developed on a common axis or branches thereof. Like solitary flowers inflorescence may be **terminal** when it is at the head of stems or branches. It is **axillary** when developed in the axils of leaves. Solitary flowers may be regarded as reduced inflorescences in which the main axis is unbranched and only one flower develops on the axis.

Parts of the inflorescence.

The main axis, bearing a single flower or a number of flowers on it, is called the **peduncle**. When the peduncle branches, each of these branches on which individual flowers are directly seated, is called a **pedicel** or **stalk**. Flowers

with such stalks are called **pedicellate**, as in *sarisha*, *nebu*, etc., while they are **sessile** when their stalks are absent, as in *apang*, *kochoo*, etc. That part of the axis, which supports the branch system of flowers and which is in continuation with the peduncle, is called **rachis**. The rachis may be elongated, flat, concave, convex or in the form of a solid fleshy head, as in *kadamba*, *surjamukhi*, etc.

In underground stems and acaulescent plants, an elongated rachis rises up to bear on it flowers and fruits. This is called a *scape*, as found in *piaj*, *rajanigandha*, *bhumichampa*, etc.

Chief types of Inflorescence.

The two chief types of inflorescence are :—

(1) **Racemose** and (2) **Cymose**. The branching of an inflorescence follows fundamentally the same laws of development as found in those of the vegetative shoot.

Racemose inflorescence.

As in racemose branching, so in racemose inflorescence, the main axis is stouter and longer than its lateral branches. The rachis goes on growing upwards and as there is no knowing when the growth of the rachis will cease, it becomes much elongated. Owing to this indefinite and unlimited growth of the rachis, racemose is also known as **indefinite**. The side-branches developed from the rachis produce flowers in acropetal order of succession, i.e. the older flowers are at the base and the younger flowers are at the apex. Flowering thus begins from the base and ends at the apex.

In some cases, rachis is short and fleshy and becomes flat, concave or convex, when the flowers on it develop from the circumference towards the centre. So the oldest flowers are at the periphery and the youngest ones are at the centre. The opening of the flowers, here, is thus not from the base to the apex but from the circumference towards the centre, i.e. **centripetal**, as found in *surjamukhi*, *ganda*, etc.

Cymose Inflorescence

In **Cymose** types, the mother axis ceases to grow when it produces daughter axes. These, too, in their turn cease to grow when they produce their branches and so on. The terminal part of the floral axis always ends in a flower, so that, the axis has a limited or definite growth. For this reason, cymose is also known as **definite**. As the terminal flower here opens first, the older flowers are in the middle while the younger flowers are at their sides. The order of development is thus **centrifugal,** as in *jui*, *tulsi*, etc.

Racemose and Cymose types compared.

RACEMOSE.	CYMOSE.
1. The growth of the inflorescence is maintained by the primary axis.	1. The growth of the infloresceuce is maintained by the development of successive branches.
2. Lateral branches do not grow so vigorously as the main axis.	2. Lateral branches grow as vigorously as the main axis.
3. Main axis usually elongated.	3. Main axis shortened.
4. Flowering sometimes centripetal but always indefinite.	4. Flowering centrifugal and definite.
5. Axis monopodial i.e. single-footed.	5. Axis sympodial i. e. joint-footed.

Advantages of Cymose types over Racemose types.

1. It is often asserted that cymose types have been derived from the racemose types.

2. In many racemose types, flowers open within a short period, and if the conditions for pollination be not favourable, there is no chance for the production of fertile seeds ; but in cymose types, as the lateral branches develop one after another, flowering is not simultaneous.

3. In racemose types, the flowers as well as the fruits are on the exposed surface. This is a danger specially in the case of young succulent fruits. In cymose types, when the flowers open, they are exposed but when their fruits are formed they remain safe within the branches.

4. In racemose types, when the apex of the elongated rachis is injured, the power of producing flowers is lost for a time, while in cymose types, the injury at the head of the main axis means the loss of a single flower only. It rather stimulates the vigorous development of lateral axes.

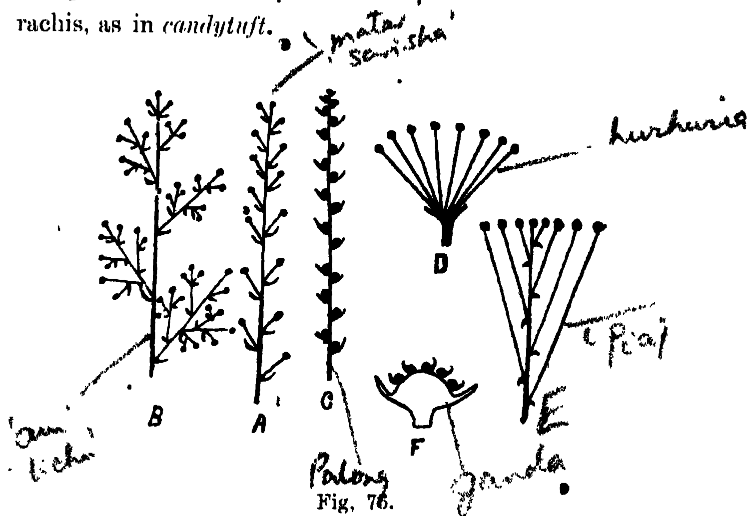
FORMS OF RACEMOSE INFLORESCENCE.

A. Rachis elongated.

1. Flowers pedicellate.

(a) **Raceme.**—This is the typical form of racemose inflorescence. The rachis goes on growing indefinitely producing flowers in acropetal order. Thus flowering is from the base to the apex. This may be **simple**, when the rachis is unbranched, as in *sarisha*, *matar*, *krishnachura*, *atashi*, etc. This may be **compound** or **panicled**, when the rachis becomes branched and flowers arise acropetally on each of the branches as in *am*, *lichu*, *shegun*.

(b) **Corymb.**—This agrees with raceme closely but the pedicels are longer and longer towards the base of the rachis, so that all the flowers are brought to the same level. This is **simple**, when the pedicels are directly on the unbranched rachis, as in *hurhuria*, *khet-papra*, etc. This may be **compound**, when the pedicels are on the branches of the rachis, as in *candytuft*.



Fig, 76.

Types of Racemose Inflorescence.
A - Simple raceme. B—Compound raceme. C—Simple spike.
D - Simple corymb. E - Simple umbel. F—Capitulum.

2. **Flowers sessile.**

(a) **Spike.**—This differs from the racemose form in this only that the pedicels are absent. This is **simple** or **compound**, according as the rachis is unbranched or branched. *Apang*, *palong*, *kalmeg*, *kantanate*, etc., are the examples of spike.

(b) **Spadix.**—This is a spike but its thick axis, bearing usually male flowers above and female flowers below, is

covered by a large fleshy or woody bract called a **spathe**. *Kochoo, kola; narikel*, are examples of spadix. Like spike, this may also be **simple** or **compound**.

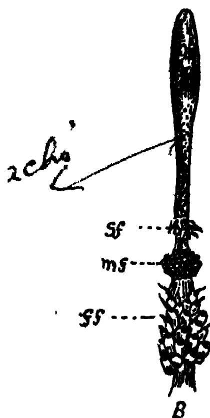


Fig. 77.
Spadix of *kochu* without spathe. sf—Sterile flowers. mf—Male flowers. ff—Female flowers.

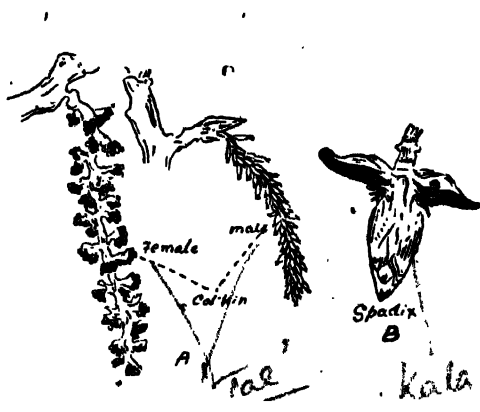


Fig. 78.
A—Male and female catkin of *pituli*.
B—Spadix of *kala*.

(c) **Catkin.**—This is a long and pendulous spike consisting of many unisexual flowers. The **male catkin** consists of male flowers only, while in **female catkin** all the flowers are female, as found in *tal, pituli, pan*, etc.

B. Rachis short.

(a) **Umbel.**—When the pedicels arise from the same point of the rachis and are of nearly equal length so that flowering is centripetal it is called an *umbel*. This is

simple, when the pedicels arise directly on the short rachis, as found in *piaj*, *halshi*, etc. It is **compound**; when the pedicels are on the branches of the rachis, as found in *shukhadarshan*, *mouri*, *dhania*, etc.

(b) **Capitate**.—In this case the rachis is very short and from one point at its head, many sessile, minute flowers arise, as found in *babla*, *lajjabati*, etc.

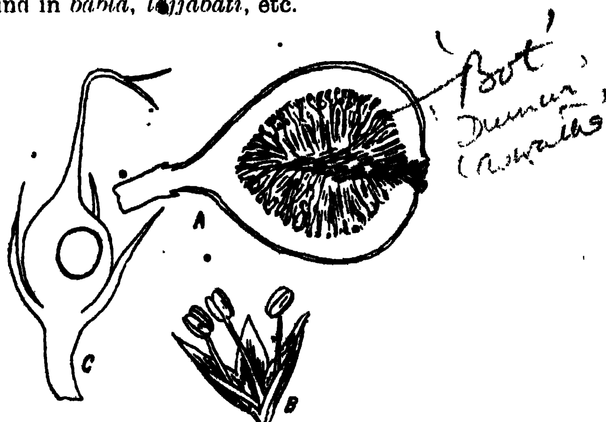


Fig. 79.
Hypanthodium of *bot*.
A—Inflorescence B—Male flower. C—Female flower.

C. Rachis in the form of a receptacle.

(a) **Capitulum**.—On the rachis, which is flat, convex or headlike, there are many small, sessile, bracteate and much crowded flowers developing centripetally. The base of the fleshy rachis is surrounded by one or several whorls of bracts forming an involucre. Usually, the flowers on the rachis are of two types—those, which are at the periphery

called **ray florets**, are more conspicuous than those at the centre called **disc florets**. This is found in *surjamukhi*, *kukursonka*, *ganda*, etc. (Fig. 82)

(b) **Hypanthodium**. Here the rachis is fleshy, hollow and more or less cup-shaped with a small opening at the top. The minute sessile flowers arise over the inner wall of the rachis, as found in *bot*, *dumur*, *aswatha*, etc. (Fig. 79)

N. B. Strictly speaking, the racemose development of the florets in hypanthodium is not so clear.

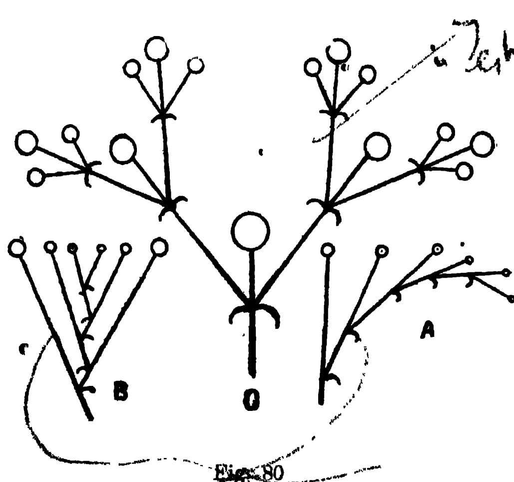


Fig. 80

Cymose type of inflorescence
A—Helicoid uniparous. B—Scorpioid uniparous.
C—Biparous Cymose.

Forms of Cymose Inflorescence

1. **Uniparous** or **monochasium**.—This is a cyme, where a single secondary axis occurs at each branching and where each successive axis terminates in a flower after

giving rise to a daughter axis. This may be **helicoid**, when all the lateral axes are always on the same side, either right or left. It is **scorpioid**, when the lateral axes are developed alternately on the right and left. In helicoid, the axis formed by the successive branches curls in the manner of a helix, but in scorpioid, the axis assumes a zig-zag form. *Hatishoor*, *hashnahena* and some plants of *dhutra* family show uniparous cymes.

2. **Biparous** or **dichasium**.—The main axis at first ends in a flower and below it arise two fork-like lateral axes, each of which behaves like the primary axis and bears two lateral axes in its turn and so on. This is found in *jui*, *lal-bharenda*, *ghentu*, etc.

3. **Multiparous** or **polychasium**.—This agrees with the dichasium but the number of lateral axes is three or more than three. The three branches are found in *sheuli*. When many branches are developed, it looks like an umbel; hence to distinguish it from the true umbel this is called a **cymose umbel** as in *rangan*. The branching here is from the centre outwards, as found in *akanda*, *bhagh-barenda* etc.

Special forms of inflorescence

1. Verticillaster.

At the axils of the opposite and decussate leaves, whorls of flowers sometimes arise. Each whorl consists of many sessile flowers which are crowded at the node and develop centripetally. This is known as **verticillaster**, as found in *dhrone*, *ghal-ghasi*, etc.

2. **Cyathium.**—This peculiar inflorescence is embraced within a cup-shaped or boot-shaped involucre in the centre of which lies the solitary, stalked and bracteate female flower surrounded by many bracteate stalked male flowers.

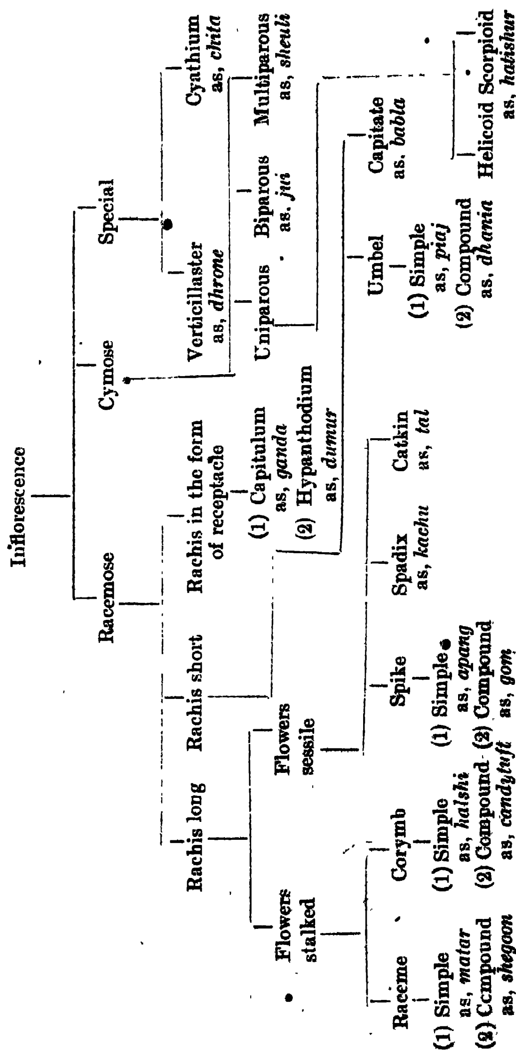


Fig. 81.

A—Verticillaster inflorescence B—Cyathium inflorescence.
b—Bract. g—Gland. mf—Male flower.
ff—Female flower in the centre.

From the margin of the involucre, glands usually appear. The whole structure looks apparently like a single flower but each male flower consists only of one male organ (stamen). This is found in *lal-pata, rangchita, teshira-mansha, mukta-jhuri, etc.*

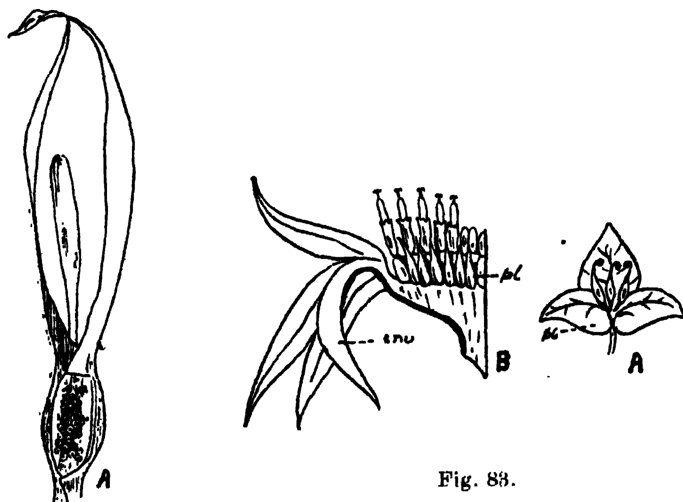
Tabular summary of inflorescence.



Bracts

Bracts are modified leaves at the axils of which flowers, solitary or in clusters, originate in the form of flower-buds and are thus protected. They vary much in size, form and colour. They may rise singly or in clusters.

Flowers are called **bracteate** when they are in the axils of bracts, as in *jaba, dhania, surjamukhi*. Flowers are **ebracteate** when bracts do not develop, as in *dhutra, begoon*, etc



82.
Spathe of *kochoo*

Fig. 83.
Bracts. A—*Baganbilas* flower. B—*Surjamukhi* (a section). pb—Petaloid bract. pl—Palea. inv—Involucre.

Bracteoles are very small, leafy bodies developed on pedicels between the flower and its bract.

Bracts may be **deciduous** when they fall off at the time of the opening of flowers or **persistent**, when they remain even after the fall of flowers, as in *narikel, baganbilash*.

Kinds of bracts.

1. **Spathe.**--This large bract is woody or fleshy and embraces the whole inflorescence. It is fleshy in *kochoo, kola*, etc., but woody and boat-shaped in *khejoor, narikel, etc.*

2. **Petaloid** bract.--When the flowers are small and their petals are absent, the bracts may become coloured and petal-like. In *lal-pata*, they are large, scarlet-red and leaf-like bodies arising in a cluster at the base of the inflorescence. In *bagan-bilash*, the rose-coloured bracts are three in number and each bears a tube-like flower at its axil.

3. **Epicalyx.**--This is a whorl of green bracts situated just at the base of the flower, as found in *jaba, kapas*, etc

4. **Involucre.**—This is also a whorl of bracts surrounding a cluster of flowers. This is found in all the flowers of *dhaniya* family, where the bracts at the base of the chief floral branches form the **general involucre** of the umbel inflorescence, while the smaller bracts in a whorl at the base of the pedicels of any branch form **partial involucre** or **involuce.**



Fig. 84.
The compound umbel of *dhania* with involucres. a—General involucre at the base of the floral branches, on each of which partial involucre is formed. b—Sheathing leaf-base.

The bracts in one or several whorls, free or fused, are found in the flowers of *surjamukhi* family.

5. **Paleae**—These are thin scaly bracts subtending the individual florets of *dhan*, *surjamukhi*, etc. **Glumes** are thin chaffy bracts found in the inflorescence of *ghas* family.

Functions of bracts.

1. When green, they act as assimilatory organs.

2. They protect usually the flower-buds or whole inflorescence from the loss of heat and disturbances of weather.

3. When coloured, other than green, they act as petals.

4. When scaly, they protect flowers as well as seeds from the attacks of the insects.

Tabular summary of bracts

Bracts

Spathe	Petaloid	Epicalyx	Involucre	Scaly
as, *kochu*	as, *lalpata*	as, *jaba*	as, *dhania*	(1) Palea. as, *dhan* (2) Glume as, *ghas*

Exercise VI

1. What is an inflorescence? Describe the various types of inflorescences.—C. U. 1932, 1922, 1917.

2. Describe the typical forms of indefinite inflorescence giving familiar examples in each case.—1916.

3. Describe, with diagrams, the inflorescence of wheat, banana, fig, mustard and *surjamukhi*. Explain the object of the inflorescence of *surjamukhi*.—C. U. 1923, 1922, 1918, 1917.

(**Hint** :—For the second part, the flowers being minute, they are aggregated in an inflorescence to make it conspicuous to the pollinating insects. The ray-florets attract insects to effect pollination of the bisexual central disc-florets)

4. Define the terms :—corymb, spadix, glume, capitulum, verticillaster, involucre and hypanthodium.—C. U. 1921, 1920, 1919.

CHAPTER VII

FLOWER

Parts of a flower.—A **flower** is a shoot modified for the purpose of reproduction. The axis of the shoot, on which floral leaves develop, is known as **thalamus**, sometimes termed **receptacle**. On it the floral leaves are inserted, usually in distinct whorls.

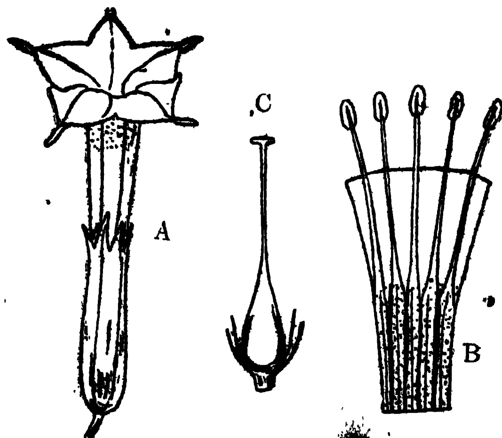


Fig. 85.

Dhutra flower. A—Full flower, B—*Corolla* with 5 stamens attached. C—Gynecium.

Usually a flower has four whorls of leaves, developed on four nodes. In a common flower, such as *dhutra*, *padma*, *kamini* or *simul*, the first whorl, arising from the first node of the thalamus, is known as **calyx**. The leaves of calyx are called **sepals**. The second whorl is **corolla**, the leaves

of which forming the whorl are **petals**. The third whorl is **androecium** consisting of modified leaves, called **stamens**. **Gynecium** or **pistil**, the last whorl, is formed from the modified leaves called **carpels**.

Each stamen, again, consists of three parts, of which the stalk-like part is called **filament**. This bears, at its head, two bags, called **pollen sacs** forming **anther**. In continuation of the filament there is a short stalk connecting the two pollen-sacs of the anther. This is **connective**. The bags contain many minute grains called **pollen-grains**

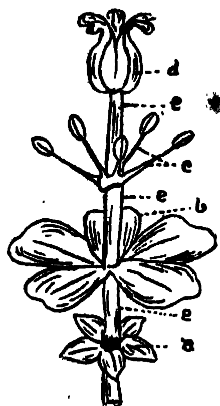


Fig. 86

Diagrammatic representation of the parts of a flower. a calyx of 5 sepals. b - corolla of 5 petals. c--Androecium of 5 stamens. d Gynecium formed of carpels. e—Thalamus.

Each carpel is differentiated into three parts, of which the basal swollen part is **ovary**. There is a slender tube at the head of the ovary. This is the **style**. The round body at the head of the style is **stigma** The ovary contains within it one or more globular bodies called **ovules**.

To prove that flower is a shoot.

1. The floral axis or thalamus consists of nodes and internodes. Leaves arise in whorls or spirally from the nodes.

2. Flowers originate in the form of flower-buds from the axils of bracts which are the special leaves.

3. The development of floral leaves in the different nodes on the axis occurs in the same way as in ordinary shoot.

4. The arrangement of floral leaves on the thalamus is governed by the ordinary laws of phyllotaxis.

5. Though the leaves on the different nodes differ in forms and functions, they are, in some cases, convertible, i. e. the leaves of one node are converted into those of another, or may show gradual transition as in *sarba-jaya*, *padma*, *shalook*, *rajani-ganda*, etc.

6. The terminal and axillary buds, common in vegetative shoot, are as a rule absent in flowers but there are cases where such buds may develop as found in some *golap*, *pepya*, *batapi-nebu*, etc. The flowering axis giving rise to a leafy shoot can be seen in *hogla*, *anaras*, etc.

7. The floral structure becomes compact due to the suppression of their successive internodes. Such suppression of internodes is also noticed in some shoots.

Functions of floral parts.—**Sepals** are usually green in colour; so they perform the function of assimilation. They also protect the other whorls of flowers when undeveloped. **Petals** are usually variously coloured and perfumed. They thus attract insects or other agents for pollination. Like sepals, they are also protective.

The main function of a flower is production of seeds. As sepals or petals indirectly help the production, they are usually known as **non-essential organs**. On the other hand, stamens and carpels are called **essential organs** as they are directly concerned with the production of seeds.

The **filaments** of stamens are to hold out the anthers in such a position that the latter are well exposed to the pollinating agents. The **anthers** are to produce the pollen which the pollinating agents carry. Similarly, the **style** of the carpels is to hold out the stigma to the pollinating agents so that the pollen has the chance of being deposited

there. **Stigma** is meant for receiving the pollen, hence this is also known as the **receptive spot.** **Ovary** is for developing within it the ovules which are the future seeds of plants.

Non-essential organs.—In many flowers, specially monocots, the sepals and the petals can not be distinguished by their colour and form. Sometimes the two whorls of calyx and corolla are so closely inserted on the thalamus or so fused together, that they look like a single whorl. These two whorls are together called **perianth** or floral envelope. Perianth is **polyphyllous,** when the leaves are all free, as in *ulat-chandal, piaj*, etc., but it is **gamophyllous,** when they are fused, as in *rajanigandha.*

A flower is **complete,** when all the four whorls of leaves are inserted on the axis in succession, as in *jaba, sarisha,* etc. When either calyx or corolla or both are absent in a flower, it is **incomplete**, as in *krishnakali, kacheo, croton.*

When either calyx or corolla is present, the incomplete flowers are **monochlamydeous,** as in *punarnaba, katanate.* When both of them are absent, the flowers are **achlamydeous,** as in *pan,pipul,* etc. When both of them are present,the flowers are **dichlamydeous,** as in *matar, dhutura.* The dichlamydeous flowers are **heterochlamydeous,** when the calyx and corolla are of different colours, as in most of the dicot flowers. They may be **homochlamydeous,** when calyx and corolla are of the same colour, as in most of the monocot flowers, e.g. *bhoomi-champa, rajani-gandha*, etc.

Essential organs.—Stamens and carpels, the essential organs, are also called **sporophylls.** The stamens are **micro-sporophylls** and the carpels, **macro-sporophylls.** When both stamens and carpels are present in

a flower, it is called **bisexual, hermaphrodite** or **monoclinous.** When either stamens or carpels are present, the flower is **unisexual** or **diclinous.** With stamens only, the flower is **staminate** or **male** and with carpels only, it is **pistillate** or **female.** The plant is **monoecious,** when both male and female flowers are borne on it, as *kumro, shasha, bharenda.* The plant is **dioecious,** when male and female flowers are on the different plants of the same species, as *tal, kea, patole.* The plant is **polygamous,** when both male and female as well as hermaphrodite flowers are on it, as *am, yab, amrha.*

Flowers are **perfect,** when both the essential organs are present. They are **imperfect,** when the flowers are unisexual. The flowers are **neuter,** when both the stamens and carpels are absent, as in some florets of *surjamukhi, kochoo,* etc.

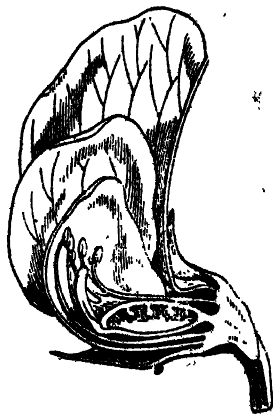


Fig. 87.
Zygomorphic flower of *matar*

Other terms of flowers :

(a) Regarding symmetry.

When the leaves of calyx and corolla are similar in form and size in each whorl, the flower is said to be **regular,** as in *tishi, poppy, mula, jaba,* etc. But when the leaves are dissimilar in form and size, i.e., some are markedly larger than the others, the flower is **irregular,** as in *bak, dhrone.* A regular flower is **actinomorphic,** when it can be cut longi-

tudinally into two equal halves through any plane. The halves must contain equal number of members of each whorl, as in *sharisha*, *mashina*, etc. An irregular flower is **zygomorphic**, when it can be cut longitudinally into two equal halves along only one plane ; excepting that plane, the flower can not be cut so as to get two equal halves, as in *aparajita*, *matar*, *tulsi*, etc. An irregular flower is **asymmetrical**, when it can not be cut longitudiully along any plane in order to get two equal halves ; the divisions thus made are widely different from each other, as in *kola*, *sarbo-joya*, etc.

(b) Regarding the number of members of whorls.

When the leaves of the four whorls are all equal in number or any multiple thereof, the flowers are **isomerous**. According to the number or multiple of that number, flowers are **dimerous**, **trimerous**, **tetramerous**, **pentamerous**, or **hexamerous**. **All monocot flowers, as a rule, are trimerous**. **Dicot flowers are usually pentamerous** though they may be dimerous or tetramerous. They are never trimerous except in a few families as of *ata*, *nona*, *champa*, etc. Thus *sharisha*, *mula* are dimerous flowers; *rajanigantha*, *lily* are trimerous ; *patharkuchi*. *labanga* are tetramerous ; *jaba*, *dhanras*, *kapas*, are all pentamerous. When the members of the whorls do not agree in their numbers, they are **anisomerous**, as in *tulsi*, *matar*, *kalmeg*.

(c) Regarding phyllotaxis.

In most of the flowers, sepals, petals, stamens and carpels are arranged in whorls on the different nodes of the thalamus. They are called **cyclic**. But, in *padma*, *shalook*, *nagphani*, the leaves are arranged spirally on the thalamus and they are called **acyclic**.

The side of a flower, that lies nearest the stem, is called **posterior** and the side, lying away from the stem, is called **anterior**.

Dicot and monocot flowers compared.—

1. Monocot flowers are mostly trimerous, but dicot flowers are usually pentamerous or tetramerous.

2. In monocot flowers, the calyx and corolla can not always be clearly distinguished, hence we use the term perianth. Flowers then are homochlamydeous while dicot flowers are usually heterochlamydeous, as the sepals here are mostly green.

THALAMUS

Thalamus or the floral axis usually consists of four nodes and three internodes. In a flower, the internodes of thalamus are usually suppressed. But when the axis elongates into prominent nodes and internodes, they appear as distinct stalks of different whorls and are named accordingly. Thus the portion of the axis bearing the perianth is known as **anthophore**. Similarly, the portion of the axis bearing androecium is called **androphore** and the axis or stalk on which the gynecium is seated is **gynophore**. The androphore and gynophore are found in the flowers of *jhumkalata* and *shada-hurhuria*.

Thalamus may be of different forms. It is club-shaped, as in *champa*, *ata*; very prominent, fleshy and in the form of an inverted cone, as in *padma*, etc; top-like, as in *shalook* and cup-shaped. as in *golap*, etc.

Flowers are so variable in structure that no two flowers of the different species are alike. The most

puzzling feature of the flowers is, that the floral whorls are never seen to occupy the same position on the floral axis of all flowers. Thus the position of the calyx may be lowermost or topmost on the thalamus. They are, therefore, termed as **inferior** or **superior**. Flowers may be constructed in three ways according to the variation of insertion of the floral leaves on the axis :—



Fig. 88.

Thalamus. A—*Jhumkalata* flower with androphore a. B—*Hurkuria* flower. a—Androphore. b—Gynophore. C—*Golap* flower. th—Thalamus abnormally growing beyond the flower.

(a) When the axis is more or less convex in form and its growing point is at the head which is occupied by the gynecium, and when the sepals, petals and stamens are inserted on the axis below the gynecium in an acropetal order, the flower is called **hypogynous**. Here the gyne-

cium with ovary is superior and the other whorls are inferior. This is found in *padma, champa, dhutra, ata*, etc.

(b) When the axis is in the form of a flat disc due to the development of its sides and the growing point is in the middle of the disc which is occupied by gynecium, and when the remaining whorls are inserted, in order, on the disc surrounding the gynecium in the middle, the flower is **perigynous**. Here the ovary also is superior and the other

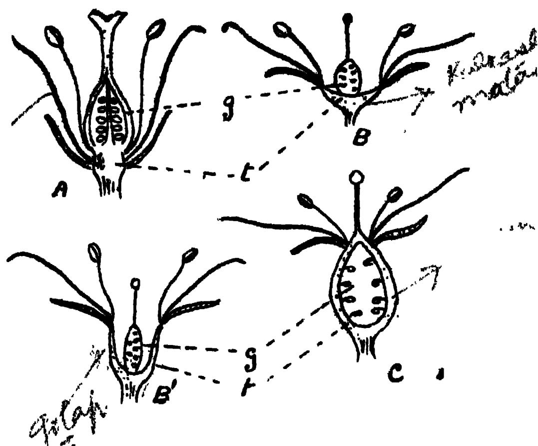


Fig. 89.
A—Hypogynous, B, B'—Perigynous and C—Epigynous flowers.
t—Thalamus ; g—Gynecium.

whorls inferior, as found in *kalkasinda, matar, bok*, etc. In some perigynons types, due to the further development of the sides of the disc, it becomes cup-shaped and at its bottom lies the growing point occupied by gynecium. Sepals, petals and stamens all arise, in order, from the rim of the cup called **calyx-tube.** Examples of this type of flower are found in *golap*.

(c) When the axis is so hollowed out that it is in the form of a deep cup to which the ovary is closely adherent and when the other whorls arise from the top of the cup, in order so that the stamens are next to the stigma the flower is **epigynous.** The ovary here is inferior and all other whorls superior Examples are found in *kumro jamrul kola surjamukhi* etc



Fig 90

Different forms of calyx A– Polysepalous calyx B – Gamosepalous calyx C– Two lipped calyx D—Epicalyx E—Deciduous calyx F—Pappus calyx H—Spurred calyx

CALYX

Forms

When the sepals of a calyx are all free, it is **polysepalous**, as, in *shankhal moola, hurhuria* But when the sepals are all united it is **gamosepalous** as in *begun, bok* When gamose-

palous, the calyx may be **tubular**, as in *dhutra* ; **bell-shaped**, as in *jaba* ; **two-lipped**, as in *matar* ; **spurred** or provided with a prolonged tube at the base, as in *dhopati* ; **saccate** or provided with a sac at the base, as in *mula*, *nastertium* ; **teeth-like** as in *rangan*. In *surjamakhi*, *ganda*, the calyx consits of two or more hairs arising from the top of the ovary. This is called **pappus**.

Duration of calyx.

When the sepals fall off at the time of opening of the flowers, the calyx is **caducous**, as in *shealkanta*, *poppy*. It is **deciduous**, when the sepals fall off after serving their functions, as in *champa*, *padma*. It is **persistent**, when the sepals remain in the flowers though other whorls fall off. This persistent calyx is necessary for the protection of young fruit. The pappus calyx is persistent for the scattering of fruitlets of *surjamukhi*, *kukursonka*, etc. In *chalta*, the, persistent five sepals are fleshy and form a part of the false fruit. In *kumro*, the superior calyx persists as a withered body, called **marcescent**. But it is **accrescent**, when it is more or less fleshy and continues to grow with the developing fruit as noticed in *begun*, *peyara*, etc.

COROLLA

Forms :—

When the petals are all free, the corolla is **polypetalous**, as in *shimul*, *jaba*. But it is **gamopetalous**, when the petals are all united with one another, as in *rangan*, *karabi*. Both the two forms may be **regular**, when the petals are all

similar in form and size, as in *torulata*. They may also be **irregular**, when the petals are dissimilar and their arrangement is not symmetrical, as in *tulsi*.

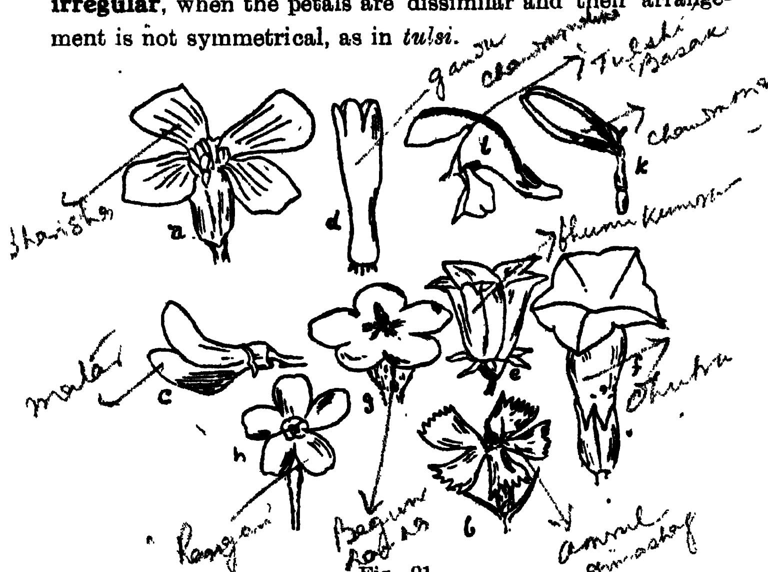


Fig. 91.

Forms of corolla. a—Cruciform. b—Caryophyllaceous. c—Papilionaceous. d Tubular. e—Campanulate f—Infundibuliform ; g—Rotate h—Hypocrateriform k—Ligulate l—Bilabiate.

A. Polypetalous

(a) Regular

(1) **Cruciform** corolla consists of four petals arranged in the form of a cross, as found in all flowers of *sharisha* family.

(2) **Rosaceous** corolla consists of five spreading petals, as in *golap*.

(3) **Caryophyllaceous** corolla has five spreading clawed petals. Each claw or the stalk-like narrow portion

of a petal is at right angles to its limb or the expanded portion, as in *gimashag*, *amrul*, etc.

(b) Irregular

(1) **Papilionaceous** corolla consists of five petals of which the largest posterior petal called **standard** or **vexillum** encloses two lateral or side-petals called **wings** or **alae** which in their turn enclose the remaining two. These two are more or less united into a boat-shaped structure called **keel** or **carina**. This is the characteristic corolla of all flowers of *matar* family.

B. Gamopetalous

(a) Regular

(1) **Tubular** corolla has four or five petals united to form a tube-like body, as found in the disc florets of *ganda*, *chandra-mallika* etc.

(2) **Campanulate** or bell-shaped, as in *bhumikumra*, *kalmi*, etc.

(3) **Infundibuliform** or funnel shaped as *tamak*, *dhutra* etc.

(4) **Rotate** or wheel shaped, where the petals are joined to form a short tube with a spreading limb which is at right angles to the tube, as in *begun*, *lanka*, *kantikari*.

(5) **Hypocrateriform** or salver shaped, where the corolla is like the rotate one but its tube is long, as in *torulata*, *rangan* etc.

(b) Irregular

(1) **Bilabiate** corolla consists of five petals fused to form two lips, the upper one overhanging over the lower. This is found in most of the flowers of *tulsi* and *basak* families.

(2) **Ligulate** corolla consists of three or five petals united to form a short tube at the base and flat or strap-shaped above, as found in the ray florets of *surjamukhi*, *chandra-mallika* etc.

(3) **Personate**--This agrees with the bilabiate type but the mouth is nearly closed by a pouch as found in *basanti*.

Corona is a ring of filamentous outgrowths arising from the wall of the corolla or lying between the corolla and the androecium, as found in *shukadarshan*, *rakta-karabi*, *akanda* etc. In *jhumkolata* these outgrowths form two or more whorls of coloured hairy bodies.

Aestivation.

This indicates the relative arrangement of floral leaves, usually in the case of sepals or petals, when they are in the bud. This corresponds to the vernation of foliage leaves. (vide page 90).

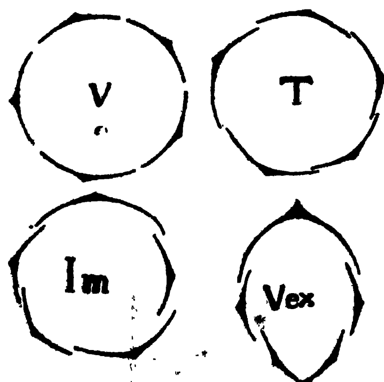


Fig. 92.
Aestivation. V—Valvate. T—Twisted. Im—Imbricate, Vex—Vexillary.

This may occur in the following ways :—

(1) **Valvate.**—The margins of sepals or petals touch each other but do not overlap, as in *nebu*, *ata*, *nona*, etc.

(2) **Contorted or twisted**.—The margins of the sepals or petals overlap each other successively in one direction only, as in *karabi*, *jaba*, *katchampa*.

(3) **Imbricate**.—Here the margins of the sepals or petals overlap each other irregularly, as in *kalkashinda*, *poppy*.

(4) **Vexillary**—Here the vexillum encloses other petals in papilionaceous corolla, as in *matar, bak, aparajita*.

ANDROECIUM

Number of stamens

According to the number of stamens in the flower it may be **monandrous**, i. e., having a single stamen, as in *lalpata*,

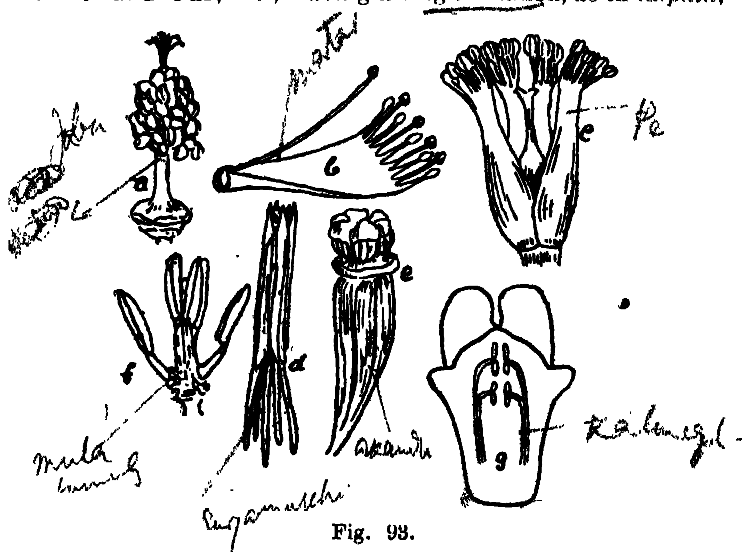


Fig. 93.

Types of Stamens. a—Monadelphous. b—Diadelphous. c—Polyadelphous d—Syngenesious. e—Gynandrous. f—Tetradynamous. g—Didynamous.

ada, halud ; **diandrous**, with two stamens, as in *jui, basak, beli* ; **triandrous**, with three stamens, as in *gom, ak* ; **tetrandrous**, with four stamens, as in *rangan* ; **pentandrous**, as in

dhutra, *begun* ; **hexandrous**, with six stamens, as in *mula*, *shukadarsan*, *dhan*, and so on.

When the stamens in one whorl are same in number as the sepals or petals, the flower is called **isostemonous**, as in *patharkuchi*, but when the number is double and the stamens are in two whorls it is **diplostemonous** as in *lily*, *piaj*, etc.

Relative lengths

(1) When the stamens in a flower are six in number, of which four are longer than the other two, they are called **tetradynamous**, as found in the stamens of *mula*, *sharisha* family.

(2) When there are four stamens of which two are longer than the other two, they are called **didynamous**, as found in the stamens of *tulsi*, *kalmegh* families.

Union of stamens

(1) When all the filaments of the stamens in a flower are united to form a single bundle and the anthers remain free, the stamens are **monadelphous**, as in most of the flowers of *jaba* family.

(2) When the stamens, after the union of the filaments, form two bundles, they are **diadelphous**, as in the flowers of *matar* family.

(3) Stamens are **polyadelphous**, when the filaments unite to form many bundles, as in *shimul*, *nebu*, *jamrul*, *peyara*, etc.

(4) When the anthers are united to form one tube and the filaments are free, the stamens are **syngenesious**, as in the disc florets of *surjamukhi*, *ganda*, etc.

(5) When the stamens are attached to the corolla by their filaments, they are **epipetalous**, as in *dhutia*, *rangan*, *karabi*, etc

(6) When the stamens are attached to the gynecium in such a way that they form a column called **gynostemium**, they are called **gynandrous**, as in *akanda*, *rasna*, etc.

(7) When the stamens are attached to the perianth leaves they are called **epiphyllous** as in *shukhadarsan*, *rajanigandha*, etc

Suppression and modification of parts

When the filament of a stamen is absent, the anther is called **sessile** But when the anthers are absent or functionless, the stamens are called **staminodes**, as in *sarbo joya*, *dulalchampa* The staminodes may be petal-like in form and serve the function of petals They are then

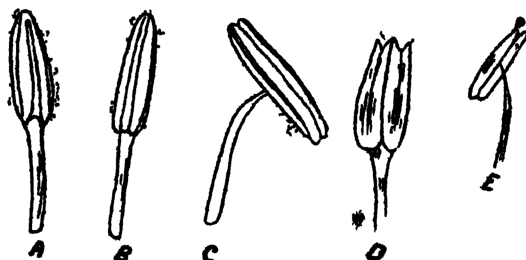


Fig 94

Attachment of Stamens A—Basifixed B D—Adnate C—Dorsifixed E—Versatile

called **petaloid staminodes**, as in *ada*, *panchamukhi jaba* In *reihi* the filaments may be branched In

kumro and allied plants, the anthers are long and wavy. They are called **sinuous**.

Attachment of anther to the filament.

When the filament is attached to the base of the anther, the stamen is **basifixed**, as in *sharisha*. It is **adnate**, when the connective can be traced easily as the apical prolongation of the filament, as in *champa*. When the attachmnet is at the back and the anther is immovable, it is **dorsifixed**, as in *shukadarsan*. When the filament is attached to the back of the anther by a point, so that the anther moves freely as if on a pivot, the stamen is **versatile**, as in *dhan*, *kul*, *lily*, etc.

When the anther turns towards the centre of the flower, the stamen is **introrse**, as in *champa*. It is **extrorse**, when the anther turns away from the centre, as in *debdaru*, *ulat-chandal*.

A stamen may be compared with an ordinary leaf, as its filament corresponds to the petiole and the anther to the blade. The anther consists of two chambers lying on two sides of the connective which corresponds to the mid-rib of a leaf. The two chambers are formed by the infolding of the right and left halves of the anther or the staminal blade towards the mid-rib. In the early stages of development of the anther, each chamber is divided into two by a partition wall which stretches from the mid-rib to the opposite wall through the cavity. Thus the anther now consists of four chambers, each of which contains numerous pollen grains. Gradually when the anther is mature, this four-chambered body becomes two-chambered, as the two partition walls formed within the chambers are absorbed and disorganized

at maturity. In the flowers of *jaba* family, due to the fusion, the anther is one-chambered. In *lajjabati* and allied plants, this may be eight-chambered by the development of partition walls in each of the four chambers in the early stage.

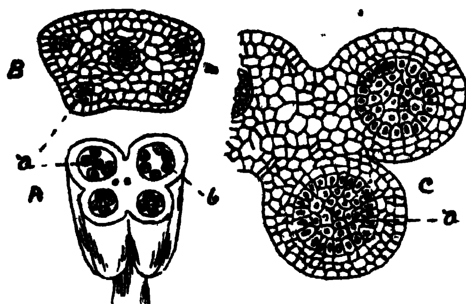


Fig. 95.
Cross section of an anther showing the chambers. B—Section in the early stage. A and C—Sections when further developed. a—Pollen grains in mother cells. b—Chamber.

Dehiscence of anther.

When the anther is mature, it bursts to liberate the pollen grains. Usually, in a dry atmosphere, the bursting occurs. There are several ways of dehiscence.

(a) **Logitudinally,** as in *jaba, champa.*

(b) **Transversely,** as in *pan, gaja-pipul.*

(c) By **pores,** as in *alu, begun, chalta.*

(d) By **valves,** as in *tezpata.*

Pollen grain

Pollen grains are minute powdery bodies developed abundantly within the chambers of the anther. They may be of various forms, viz. oval, spherical, triangular, etc. In *akanda,*

rasna, etc., many of the grains cohere together by a sticky secretion to form a single pollen mass, called **pollinium.**

Each grain has two coats. The outer protective coat, called **extine**, is thick and cuticularised. In most of the grains, specially those which are carried away by insects,

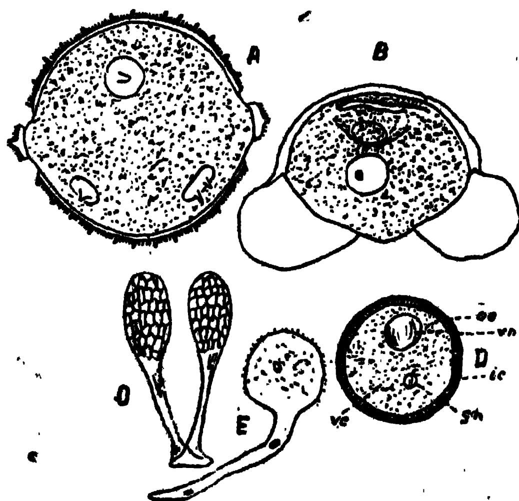


Fig 96

Pollen grains. A—*Kumro* grain. B—*Pine* grain. C—Pollinium of *Rasna*. D—A developing grain. oc—Extine. ic—Intine. E—A grain with pollen tube.

the outer surface of the extine has many spines or ridges. In other grains, these are absent and the grains are smooth-walled. In *pines*, there develop two large bladder-like expansions formed by the extine on the two sides,—so that the grain may easily be blown by wind. The extine is not uniformly thickened, but the inner coat called **intine** is uniformly thin and soft. When the grain is carried to the

mature stigma, it germinates there resulting in the formation of a tube-like body called **pollen tube**.

Adhesion and **cohesion**

The union of similar floral members is termed **cohesion** and that of dissimilar members, **adhesion**. Thus union, between sepals forming *gamosepalous* calyx, is cohesion. Similarly *gamopetalous*, *monadelphous*, *diadelphous*, *syngenesious*, etc., structures are the results of cohesion. On the other hand, *epipetalous* and *gynandrous* structures are the results of adhesion.

GYNECIUM OR PISTIL

When there is only one carpel in the gynecium, it is **simple** or **monocarpellary**, as in *shim*, *barbaty*. It is **compound** or **polycarpellary**, when the carpels are more than one. When two or more carpels are combined to form a single body, it is **syncarpous**, as in *begoon*, *sharshe*; when the carpels remain free and quite distinct from each other, it is **apocarpous**, as in *champa*, *padma*, etc.

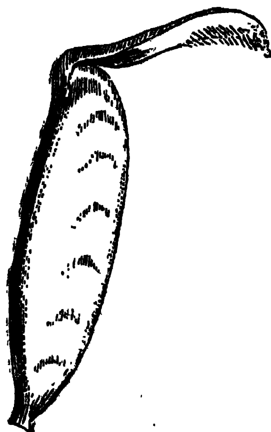


Fig. 97.
Simple pistil of *matar* flower.

In apocarpous pistil, according to the number of carpels separate ovaries are formed, all attached to the thalamus of the flower in several rows, each having a distinct style and stigma on it. In syncarpous pistil, union may be complete involving ovaries, styles and

stigmas, or it may occur at least in one of the three regions of the pistil. Usually, the ovaries and styles are fused, as in *surjamukhi*, *jaba*, etc., but their stigmas are free. In *tishi*, *pink*, *gima*, the ovaries are united but their styles and stigmas remain free. In *Karabi*, *kurchi*, *akanda*, etc., fusion occurs at their stigmas and styles. In angiosperms, generally, a carpel is differentiated into three parts, viz. ovary, style and stigma. Ovary or the future fruit is the closed chamber to enclose within it one or more ovules. In gymnosperms, the carpel is not divided into ovary, style and stigma; this undifferentiated carpel is in the form of a scale.

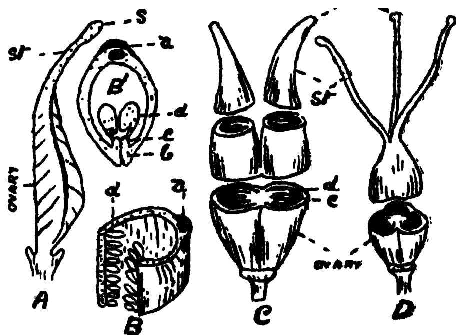


Fig. 98.

Pistil. A—Monocarpellary pistil. B, B′—Same in cross section. C—Bicarpellary pistil. D—Tricarpellary pistil. s—Stigma. st—Style. a—Dorsal suture. b—Ventral suture. c—Placenta. d—Ovule.

The carpel, if compared with a leaf, has no corresponding stalk. The style corresponds to the leaf-apex, which terminates with a special point or stigma. The two halves, on the two sides of the mid-rib, become fused at their

margins to produce a single chamber in a single pistil ; but many chambers may be formed in a compound pistil. These chambers are called **loculi** or **cells**. Thus ovary may be **unilocular** or one-celled, as in *matar, bok* ; **bilocular** or two-celled and **trilocular** or three-celled, and so on. In a syncarpous pistil, the number of carpels may be determined from the number of free stigmas at its head.

The ovary of a carpel has two **sutures** or lines, one of which, corresponding to the fused margins of the carpellary leaf and facing the axis of the plant,is called **ventral suture**, while the other, corresponding to the mid-rib of the carpellary leaf, is called **dorsal suture**.

Style

Style is single in apocarpous gynecium, but in syncarpous gynecium, styles may be united into one. It is long, as in *jaba*, *dhutra* or short, as in *champa*. It is coloured and petal-like, as in *sarba-jaya*. Sometimes, it is absent in the flower, when the stigma is **sessile**, as in *chalta*, *poppy*, etc.

When the ovary is marked at its top by depressions, so that, the ovary becomes lobed and the style arises from the depressed point appearing as the prolongation of the thalamus, the style is called **gynobasic**, as in *tulsi*, *dhrone* etc.

Stigma

It is the terminal part of the style. When it is mature, it may receive the pollen grains which germinate on it. It may be feathery, sticky, fleshy, single, or branched. The number of stigmas is two in *surjamukhi*, three *in kumro*, five in *jaba*, and so on.

Placentation.

Placentas are cellular outgrowths developed on the inner surface of the ovary from the united margins of the carpellary leaves or from the floral axis. Rarely, they arise from the base of the ovary. Ovules are borne on the swollen surface of the placenta which may hold one or more ovules



Fig. 99.

Style and stigmas. a—Gynobasic style. b—Sessile, c—Feathery, d—Pentangular, e—Dumb-bell shaped, f—Foliaceous, g—Lobed stigmas. h—Style of *kumra*. st—Style, sp—Stigma.

within the ovary. The manner, in which the placentas are arranged or distributed on the inner side of the ovary, is called **placentation**.

The types of placentation are as follows :—

(1) **Marginal**—The ovules develop on the placenta, arising from the ventral suture of the monocarpellary leaf as

found in *matar* and other flowers of the same family. The ovary in this case is simple and unilocular.

(2) **Parietal**—This occurs in unilocular ovary belonging to two or more carpels. The placentas with the ovules arise from the united margins of the neighbouring carpels as *jhumkolata*, *sarisha*, *kumro*, etc.

(3) **Axile**—This also occurs in polycarpellary syncarpous ovary which is not one-celled but divided into as many chambers as there are carpels. The margins of each carpellary leaf unite and meet in the centre, where an **axis** is formed. The placentas with the ovules grow from

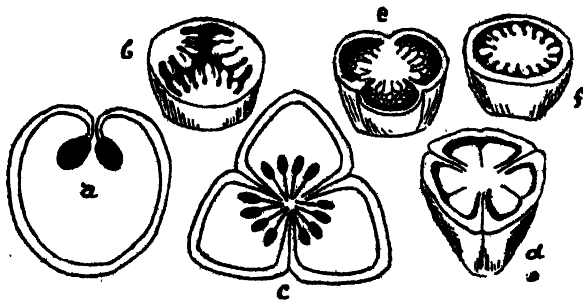


Fig. 100.
Placentation. a—Marginal. b—Parietal. c, d, e,—Axile. f Free-central.

this axis in each of the chambers formed. This is the only type of placentation in which the ovary is two or more chambered. This is found in *jaba* and *dhutra* families.

(4) **Free-central**—This occurs in unilocular ovary belonging to many carpels. The placentas, with the ovules, grow on the central axis, which is the prolongation of the thalamus within the cavity of the ovary. The ovules, in the centre, are free from the inner wall of the ovary, hence the

name of the placentation arises. This is found in the ovaries of the *gima* 'family.

(5) **Basal**—This occurs in unilocular ovary in which the single erect ovule is held by an axis at the base of the ovary as found in the ovaries of *surjamukhi* family. This type is a modification of the free-central one.

Ovules.

Ovules are oval bodies arising from the placentas within the ovary. Each ovule is seated on a stalk, called **funicle**. The point, where the funicle is attached to the ovule, is called **hilum**. The main body or the central mass of the ovule is known as **nucellus**. The ovule has usually two coats which completety enclose it, leaving a small opening at the top. The opening is called **micropyle** and the coats are **integuments**, outer and inner. The basal region of the nucellus, from which the integuments arise,is called **chalaza**.

Forms of ovules.

Four different forms of ovules arise according to the different positions of the funicle, nucellus and chalaza. They are as follows :—

(1) **Orthotropous** or straight—The ovule stands as an erect body, so that the micropyle at the top and the chalaza at the base lie in one and the same straight line. This is found in *chukopalang*, *pan*, *golmarich*. etc.

(2) **Anatropous** or inverted—The ovule is inverted completely, so that the funicle is unusually elongated. Chalaza is removed to the apex and the micropyle at the base of the ovule. Thus, micropyle, nucellus and chalaza

are in one line, and funicle runs closely by the side of the ovule. The long funicle, cohering with integuments, forms a ridge called **raphe**, which connects chalaza and hilum. This is a very common form of ovule found in many dicot flowers, as in *sharisha*, *kumro*, *surjamukhi*, *shim*, *barbati* etc.

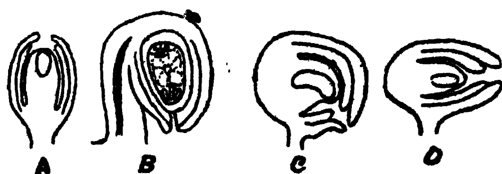


Fig. 101.
Forms of ovules. A—Orthotropous. B—Anatropous. C—Campylotropous. D—Amphitropous.

(3) **Campylotropous** or bent—The ovule is bent upon itself in such a way that micropyle and chalaza are close to each other. The micropyle is not at the top of the ovule but very near to hilum, as found in *gima* and *krishnakali*.

(4) **Amphitropous**—The ovule is twisted in such a way that the axis of the ovule is at right angles to the funicle, as found in *poppy*.

Summary of Chapter VII

1. Flower is a modified shoot of which the axis is **thalamus.** Four whorls of leaves arise on the axis. They are :—(1) **Calyx** composed of **sepals,** (2) **corolla,** of **petals,** (3) **androecium,** of **stamens,** (4) **gynecium,** of **carpels.**

A stamen consists of **filament, anther** and **connective** A carpel consists of **ovary, style** and **stigma.**

2. Flower is a shoot, as it agrees with the latter regarding origin, structure, development, phyllotaxis and in some cases regarding the production of terminal and axillary buds.

3. Sepals and petals are **non-essential organs**, while stamens and carpels are **essential organs**.

4. Sepals and petals together form **perianth**. This may be **polyphyllous** or **gamophyllous**. Flower is **complete**, when all the whorls are present. It is **incomplete**, when one of the whorls is absent. Flower may be **achlamydeous**, **monochlamydeous**, **homochlamydeous**, **heterochlamydeous**, and **dichlamydeous** according to the presence or absence of sepals, petals or both.

5. Flowers may be **bisexual**, **unisexual**, or **neuter** according to the presence or absence of stamens, carpels or both. When two types of unisexual flowers are on the same plant, it is **monoecious**, but it is **dioecious**, when they are on two different plants.

6. According to the symmetry in the flowers, they may be **actinomorphic**, **zygomorphic** or **asymmetrical**. Flowers may be **isomerous** or **anisomerous**, depending on the equality or in-equality of the number of members. Flowers may be **cyclic** or **acyclic**, when the floral leaves are in different whorls or in a spiral line on the axis.

7. Thalamus, elongating in its different internodes, forms **anthophore, androphore** or **gynophore**. According to the variation of insertion of floral leaves,the flowers may be **hypogynous, perigynous** or **epigynous**.

8. Calyx may be **gamosepalous** or **polysepalous**, when the sepals are united or free. Calyx may be **caducous**, **deciduous** or **persistent** ; **superior** or **inferior**.

9. Corolla may be **gamopetalous** or **polypetalous**, when the petals are free or united. It may also be **regular** or **irregular**. The regular forms are **cruciform**, **caryophyllaceous**, **rosaceous**, **tubular**, **bell-shaped**, **funnel-shaped**, **wheel-shaped** and **salver-shaped**. The irregular forms are **papilionaceous**, **bilabiate**, **ligulate**, and **personate**.

10. Aestivation may be **valvate**, **imbricate**, **twisted** and **vexillary**. Aestivation is the arrangement of floral leaves in the bud.

11. According to the number of stamens,they may be **monandrous**

diandrous, **triandrous**, etc. When four stamens are longer than the other two, they are **tetradynamous**. They may be **monadelphous** or **polyadelphous** according to the number of bundles the filaments form, when united. When all the anthers are united, they are **syngenesious**. They are **epipetalous** or **gynandrous**, when the stamens are attached to the petals or carpels. They are **basifixed**, **dorsifixed** and **versatile** when filaments are attached to anthers differently.

12. Union of similar members is **cohesion** and that of dissimilar members is **adhesion**

13. Gynecium may be **apocarpous** or **syncarpous**, when the carpels are free or united. Ovary may be **unilocular**, **bilocular**, etc.,

14. **Placentation** is the arrangement of placentas within the ovary. This may be **marginal**, **parietal**, **axile**, **free-central** or **basal**.

15. An ovule consists of (a) a **nucellus**, the main body, (b) two **integuments**, and (c) a **stalk** or **funicle**. The different forms of ovules are **orthotropous**, **anatropous**, **campylotropous** and **amphitropous**.

Exercise VII.

1. Describe the principal types of corolla with sketches and examples.—C. U. 1930

2. Describe the various modes of insertion of the floral leaves on the thalamus.—C. U. 1920. Or, describe, with examples, the structure of hypogynous, perigynous and epigynous flowers—C. U. 1931, 1916.

(**Hint** :—The second question explains the first one).

3. What are pollen grains ? Describe their microscopic structure. What are their functions ?—C.U. 1912.

4. What is placentation ? Describe, with examples and sketches, the various forms of placentation and types of ovules.—C.U. 1928, 1926.

5. Explain clearly the difference between 'adhesion and cohesion' and define the terms, citing examples, where necessary—monoecious, monochlamydeous, anatropous, zygomorphic, hypogynous, di-dynamous, tetradynamous, epicalyx, syngenesious, monadelphous, papilionaceous, sinuous, gynandrous, staminode, connective, vexillum, pollinium, pappus, gynobasic, corona.—C. U. 1933, 1923, 1921, 1920, 1917, 1916, 1910.

CHAPTER VIII

POLLINATION

Pollination is the process of transference of mature pollen grains from the anther to the mature stigmatic surface or direct to the ovule, in the case of gymnosperms. This process is very important to the plants, as without it, production of fertilised ovules is impossible. We know that soon after transference, the pollen grains begin to germinate on the stigma, as a result of which pollen tubes are found to pass through the style and then to reach the ovule.

Kinds of pollination.

When pollen grains coming from the anthers, pollinate the stigma of the same flower, the process is called **self-pollination** or **autogamy**. In order to effect this, the anthers and stigma should be in the same flower and mature at the same time.

When the pollen of one flower pollinates the stigma of another flower of the same species, the process is **cross-pollination**, **allogamy** or intercrossing. The two flowers concerned are mostly of the same species, or rarely of different species of the same genus.

The structures of the most of the flowers are such as are adapted for cross-pollination. In many cases, where self-pollination takes place, it may be due to the failure of intercrossing.

Effects of pollination : fertilisation

When the pollen grain is mature, some changes occur in it which go on even after its transference to the surface of the stigma. As a result of the changes, the inner wall of the grain becomes elongated forming a pollen-tube within which newly formed male sexual cells enter. By the absorption of sugary secretion of the stigma, the pollen-tube passes through the stigma and the style, and at last reaches the micropyle of the ovule and comes upon the nucellus. Penetrating the nucellus, it meets the female sexual cell. Here the male cell unites with the female cell and fertilises it. This process of union is called **fertilisation.**

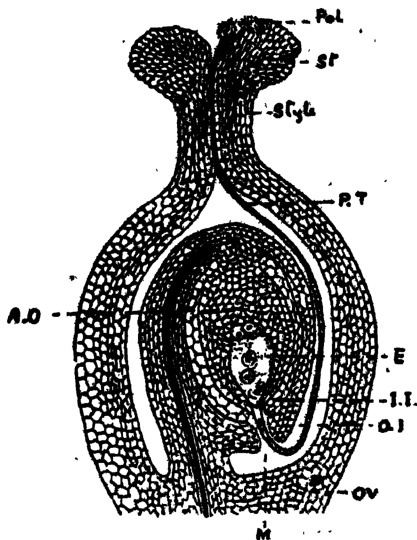


Fig. 102.

Process of Pollination and fertilisation A.O—Anatropous ovule. Pol—Pollen grain. St—Stigma. P. T.—Pollen tube. E—Embryosac. I.T.—inner integument O. I.—Outer integument. Ov—Ovary. M—Micropyle.

Pollination does not always lead to fertilisation. Even when pollination is successful, the formation of seeds and fruits does not occur in many plants as, *jaba*, *katchampa*, *Rangoon-creeper*, etc.

Autogamy and allogamy compared.

In self-pollination leading to self-fertilisation, there is the fusion of practically similar characters, as both the male and female cells come from the same parent plant. In allogamy which leads to cross-fertilisation, there is the mixing of more or less dissimilar characters, specially when the plants producing male and female cells live far apart and under different external conditions. It is also observed as the results of experiments that the seeds of cross-fertilisation are generally more numerous and give rise to offspring superior in strength, height, weight and fertility, etc. to those produced from seeds of self-fertilisation. Moreover, the seedlings of cross-fertilised seeds have greater capacity for struggling successfully with the hardships they may have to encounter during germination.

There are some disadvantages on the side of cross-pollination. Plants are to produce many pollen grains all of which are not carried away by the pollinating agents, so all are not useful for pollination. Again, for making the flowers attractive to the insects, flies and other agents, plants are to spend some amount of their materials for colour, honey and perfume. In exchange for this extra expenditure made by the plants, they gain very little. Moreover, much of the pollen is used as food for the insect visitors and even a larger quantity is lost during transit.

For cross-pollination, the plants are purely dependant on the presence and activity of the pollinating agents. So, when the agents are absent, for some reasons or other, the intercrossing fails. Thus, cross pollination becomes

in this sense, uncertain while it is the certainty of self-pollination which is its chief advantage.

Agents for cross-pollination in relation to flowers.

Pollen grains have no power of locomotion. In cross-pollination, for carrying the pollen from the anther of one flower and then depositing the same to the stigma of another flower, agents are required. The chief agents are **water, wind, insects, birds, slugs, snails,** etc. According to the agents employed, the flowers are named as follows :—

1. **Entomophilous** or insect-pollinated, as *tulsi, padma, jaba*, etc.

2. **Anemophilous** or wind-pollinated, as flowers of *dhan* family, *pine*, etc.

3. **Hydrophilous** or water pollinated, as *jhanji, pata-shaola*, etc.

4. **Ornithophilous** or bird-pollinated, as *simul, madar* etc.

Characters of entomophilous flowers

(1) The flowers are usually large and conspicuous. If small, they are aggregated in an inflorescence, to form a prominent mass, as *surjamukhi, dhaniya*, etc. (2) Petals are usually highly coloured, but in case the petals are wanting, sepals or bracts become petaloid, as in *lalpata, bayanbilas, kola*, etc. (3) Insects pollinate the stigmas without their knowledge. They usually visit the flowers in search of food. Flowers not only provide them with food present in their honey-secreting nectaries but

develop colour, perfume, etc. to allure them. (4) The pollen grains have ridges or spines on the outer surface, so that they may easily be attached to the insect-bodies. (5) There are some flowers, called **pollen flowers,** where most of the pollen is offered to the insects as their food, as *shealkanta*, *champa*, etc. (6) In many flowers the petals are structured such that insects landing on them can easily trace the paths leading to nectaries, called **honey-guides**, as *basak*, *dhanras*, etc. (7) The stigma is mostly sticky or hairy, where the hairs secrete the sugary fluid.

Characters of anemophilous flowers

(1) The flowers, pollinated by wind, are usually small, inconspicuous, and not at all showy. There is no colour, perfume or honey in the flowers. (2) The sepals or petals may be totally absent or inconspicuous, as in *pine*, or they may be replaced by scales, as in *dhan*, *gom*, *ak*, etc. (3) Pollen grains are produced in abundance, as majority of them fail to reach the female flowers. (4) The grains are light, minute, dry and smooth-walled, so there is no chance of being arrested by the leaves where they roll off readily. (5) In *pine*, they are provided with two bladder-like expansions which keep them afloat in the air for a long time. (6) In *dhan*, *gom* etc, the anthers are versatile. The stamens, in these cases, are extrorse and pendulous. (7) Stigmas may be long, branched or feathery, as in *ghas*, when a large surface is exposed to receive even the stray grains carried by wind. (8) During pollination, the plants may be defoliated, as *petuli*, *jeoli*, etc. or in some cases, the rachis is raised much above the leaves, so that the flowers are well exposed to the wind.

Contrivances favouring cross-pollination

(1) **Dicliny.**—In unisexual flowers, as stamens and carpels are not both in the same flowers, self-pollination is an impossibility. Cross-pollination is then only possible. When the plants are monoecious, inter-crossing may occur between flowers of the same plant, as *kumro*, *lau*, etc. When the plants are dioecious, inter-crossing takes place between flowers of different plants of the same species, as *tal*, *potole*, *pituli*, etc.

(2) **Dichogamy.**—In bisexual flowers, the stamens and carpels may mature at different times. So, in some flowers when the anthers are mature and shed their grains, their stigmas are too immature to receive them. These flowers are called **protandrous,** as *jaba*, *surjamukhi*, *basak*, *dhaniya*, etc. In other flowers, when their stigmas are mature and are ready to receive the grains, their own anthers are immature. Thus the stigmas have to be pollinated by foreign pollen long before the grains of the same flower are shed. These are known as **protogynous** flowers, as in *kola*, *sharisha*, *rungchita*, *champa*, etc.

(3) **Self-sterility.**—There are bisexual flowers in which the anthers and stigmas mature at the same time but still self-pollination is precluded, as these flowers, on account of their inherent property, are never fertilised by their own pollen. These flowers are self-sterile, as found in *jhumkolata*. In some *orchids*, it is curious to observe that when the pollen grains of these flowers are allowed to fall on their own stigmas, the latter may be disorganised as the result.

(4) **Herkogamy.**—In some bisexual flowers self-pollination is avoided by the peculiar arrangement and unfavourable position of anthers and stigmas. The staminal heads are situated at such a great distance from the centre of the flower, that when the grains are shed, they have very little chance of pollinating their stigmas, as noticed in the flowers of *ghentu*, *ulat-chandal*, etc. In some flowers, as *akanda*, *orchids*, etc., their pollinia or pollen-masses formed can only be removed by bees so checking autogamy.

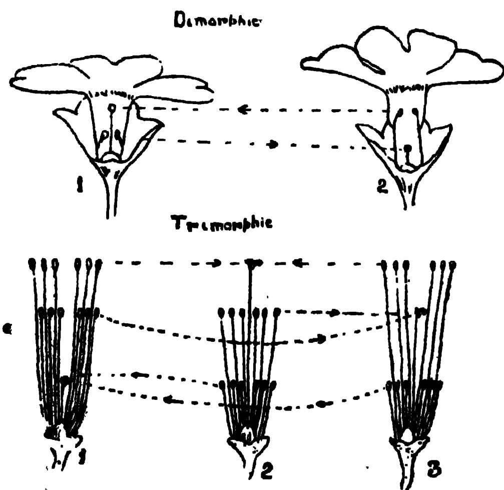


Fig. 103.
Dimorphic and trimorphic flowers.

(5) **Heterostyly.**—Self-pollination becomes impossible in some bisexual flowers, when two or three types of them appear on the plants with the styles and stamens of different lengths.

The plants are called **dimorphic**, when they bear on them two kinds of such flowers. One type of them has a long style but short stamens while the other type has long stamens but a short style. An insect, in course of its visit, touches the anthers of long stamens and carries pollen to the other flower with long style. Similarly, short stamens of one flower pollinate the stigma on the short style of another flower through the agency of insects. In these cases, the pollination is legitimate, and this condition, of producing such two types of flowers, is known as **dimorphism**. This is found in the flowers of *ban-naranga*, *jui*, *mallika*, etc.

Similarly, plants are trimorphic when they bear on them three types of flowers. Trimorphism is found in *jarul*, *dalim*, etc.

Contrivances for self-pollination

In spite of its many disadvantages, self-pollination takes place in a large number of flowering plants and even self-pollination and cross-pollination may go on side by side in the same plant.

(1) **Homogamy.**—There are some flowers, called **homogamous**, in which the anthers and the stigmas mature at the same time. They are usually small and without honey and perfume, as found in *amrul*.

(2) **Cleistogamy.**—Most of the flowers open when mature, but **cleistogamous** flowers are those which are small and do not open even when their reproductive organs are mature. They look like green flower-buds and grow in the shady parts of plants or sometimes underground. The

mature stamens and styles are so close together that there can not but be self-pollination. Plants bearing cleistogamous flowers produce also **chasmogamous** or open flowers as they can not fully depend on the former. This is found in *kanchira*, *kantal*, *alak'a'a*, etc. In the first two cases, flowers grow also underground.

(3) **Curling back of stigma or filament** —In *jaba*, *surjamukhi*, *phalsa*, etc., when inter-crossing fails due to the absence of pollinating agents, the stigmas protrude and curl back in such a way as to reach the region of mature anther to effect self-pollination. On the other hand, in *nagphani*, *ghentu*, etc., the filaments curve to meet the mature stigma.

(4) **Closing up of petals.**—In *krishnakali*, *kalmi*, *torulata*, etc. when there is the failure of intercrossing, the petals, on which the pollen grains are shed, close up so that the grains, coming now in contact with the mature stigma, pollinate it.

(5) **Elongation of filament or style.** - In *moola*, *sharisha*, there are two stamens shorter than the other four which are useful for cross-pollination. When insect-visit fails, the shorter stamens elongate and come to the same level with the stigma to pollinate it. In *gandharaj*, the style elongates to receive pollens of the discharging anther.

Summary of Chapter VIII

1. Pollination is the transference of pollen from the anther to the stigma.

2. Pollination takes place in two ways.—(a) **Self-pollination**, when the pollen of A falls on the stigma of A.

(b) **Cross-pollination**, when the pollen of A falls on the stigma of B.

3. According to the agents, flowers may be **entomophilous, anemophilous, hydrophilous, ornithophilous**, etc.

4. Conditions favouring cross-pollination :—Dicliny, (2) Dichogamy, (3) Self-sterility, (4) Herkogamy, (5) Heterostyly.

5. Conditions favouring self-pollination :—(1) Homogamy, (2) Cleistogamy, (3) Curling of stigmas or filaments, (4) Closing of petals, (5) Elongation of styles or filaments.

6. Characters of insect-pollinated flowers.

(a) Flowers are large or aggregated, when small. (b) Bracts may be coloured. (c) They may possess colour, perfume or honey. (d) They may offer pollen as food for the agents. (e) They may have honey-guides. (f) The stigmas are hairy or sticky.

7 Characters of wind-pollinated flowers—

(a) The flowers have no colour, perfume or honey. (b) Sepals or petals are absent or scales appear in their places. (c) Plants become defoliated or the rachis is long. (d) Pollens are many, light, dry or with expansions. (e) Anthers are versatile. (f) Stigmas are feathery,

Exercise VIII.

1. What are the different methods by which pollination is effected ? What is cross-pollination.—C. U. 1914, 1913, 1909.

2. How would you recognise that a certain flower is a wind-pollinated one ? What are the advantages and disadvantages of this mode of pollination.—C. U. 1912.

(**Hint** :—For the second part, consult advantages and disadvantages page 146).

3. Give a short summary of the various contrivances favouring cross-fertilisation of plants.—C. U. 1929, 1918.

CHAPTER IX

FRUIT

When pollination and fertilisation are over, all the parts of a flower may fall off excepting the ovary. We notice that when stamens and carpels are mature, the protective sepals become functionless, hence they wither and fall off. Petals are of no service to the plants when insects have been attracted and pollination has thus been effected. Stamens also become useless when their pollen has dropped or has been taken away by the pollinating agents. So, they wither and are disconnected from the plants. Last of all, the styles and stigmas fall off, when the germination of the pollen is complete, and the pollen-tube, passing through the styles and stigmas, has helped the union of the two sexual cells. Thus all the parts of the flower may vanish after discharging their respective functions except the ovary which remains in the flower to develop in connection with the formation of fruit.

Definition of fruit.

Fruit is the result of all the changes that take place in the ovary and sometimes also in other persistent parts of the flower induced by fertilisation. If the ovules in the ovary remain unfertilised, normally there is no further growth of the ovary and the formation of fruit is impossible.

True and false fruits.

Fruit, arising from ovary only, is **true**. But there are fruits which arise not only from the ovary but all other persistent parts of the flower which develop, become fleshy and take part along with the ovary in the formation of the fruits. These are known as **spurious or false fruits**. The well-known example is *chalta*, where besides the persistent free ovaries, the five sepals become fleshy and take part in the formation of the fruit. In *tepari*, the thin membranous, persistent calyx encloses the fruit. Sometimes the stimulus of fertilisation extends from the ovary not only to the sepals but also to bracts, and in some cases, even up to thalamus and peduncle. Thus, fruits arising from inferior ovaries may be taken as spurious, as the deep cup to which the ovary is adherent, is nothing but thalamus. The fruits of *kumro*, *shasha*, *peyara*, *kola*, etc., are all spurious. *Hijli-badam*, with its persistent and well-developed fleshy peduncle, is another example of false fruits. Similarly, *anaras*, *dumur*, *kantal*, with their persistent rachis, are all false fruits.

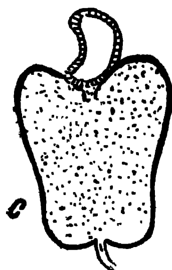


Fig. 104.
False fruits of *Hijili-badam*
c -- Peduncle

Parts of a true fruit.

The wall of the true fruit, meant for protecting and enclosing the seed or seeds within it, is known as the **pericarp**. In dry fruits, this is usually simple and thin, but thick and fleshy in fleshy fruits in some of which the three layers can be distinguished as follows :—

(a) **Epicarp** or the outermost layer representing the skin of the fruit. This is smooth and shining in *am*, *amrah*, etc. In *dhutra*, it is provided with prickles.

(b) **Mesocarp** or the middle layer which is usually fleshy and fibrous.

(c) **Endocarp** or the last layer which contains seed or seeds. This is called **stone** when it is very hard.

Functions of pericarp.

(1) It is chiefly used as a protective case for the seeds, as in *matar*.

(2) It helps the scattering of seeds by wind when it is winged, as in *madhobilata*, *chupri-alu*.

(3) The dehiscence of it is a contrivance for the dispersal of seeds, as in *dopati*.

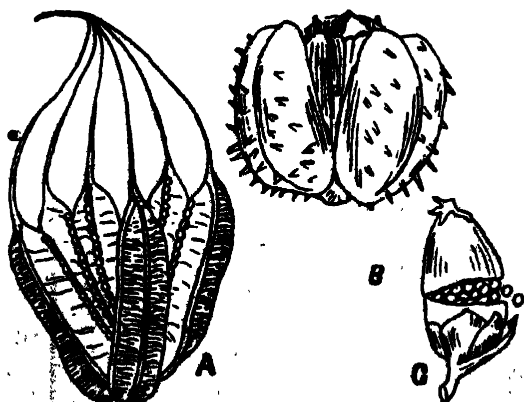


Fig 105.

its. A—*Ishermul* B—*Rethi*. C—Nuneyshak.

(4) It maintains sufficient temperature required during as in *dhan*.

(5) When fibrous, it helps the seeds to float on water in connection with their dispersal to distant localities, as in *narikel.*

Dehiscence of fruits.

Fruits with a dry pericarp dehisce in most cases in order to liberate their seeds when mature. Indehiscent dry fruits do not liberate their seeds. Fleshy fruits are usually indehiscent with a few exceptions, as *uchhe, phuti, dhundul,* etc.

There are several ways in which dehiscence occurs :—

A. Regular

(a) In unilocular ovary with marginal placentation.

1, **Sutural.**—Dehiscenc takes place along the sutures —dorsal, ventral or both. The parts, into which the pericarp breaks up, are called **valves.** *Matar, akanda, karabi, shim,* etc. fruits dehisce along their sutures.

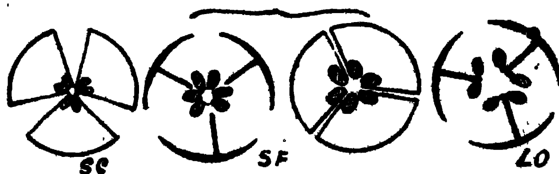


Fig. 106.

Dehiscence of fruits. Lo—Loculicidal. Sc—Septicidal. Sf Septifragal.

(b) In multilocular ovary with axile placentation.

1. **Septicidal.**—Dehiscence occurs along the middle of the septa or partition walls. As each valve corresponds to a carpel, the fruit is separated into as many valves as there are carpels, as in *rerhi, ishermool, tishi,* etc.

2. **Loculicidal.**—Dehiscence occurs along the dorsal sutures of the carpels. Each valve, separated from the central axis, consists of a partition wall which remains intact, as in *shimool*, *kapas*, etc.

3. **Septifragal.**—Dehiscence takes place as in loculicidal or septicidal ways, but owing to the rupture of partition walls, the seeds remain attached to the central axis, as in *dhutra*.

B. Irregular.

1. **Transverse.**—Fruits dehisce in such a way that the upper part of the pericarp is separated from the lower, like the lid of a box, as in *morogphul*, *nooney-shag*, etc.

2. **Porous.**—Fruits dehisce to liberate the seeds through pores formed at the apex or base of the capsule, as *shealkanta*, *poppy*, etc.

Chief Classes of fruits

There are three chief classes of fruits ;—

A. **Simple fruit** is formed from a single flower having monocarpellary or syncarpous polycarpellary ovary, as in *sharisha*, *am*, *narikel*, etc.

B. **Aggregate fruit** is formed from a single flower having apocarpous ovaries, as in *champa*, *padma*, *ata*, etc.

C. **Compound** or **multiple fruit** is formed from many flowers at a time, all belonging to the same inflorescence, as in *kantal*, *anaras*, *dumoor*, etc.

Fruits are **superior**, when they arise from superior ovaries. They are **inferior** when arising from inferior ovaries.

A. Simple Fruits.

They may be **dry** or **fleshy**. **Dry** fruits are further classified into **dehiscent** and **indehiscent**.

I. **Dry dehiscent fruits** may be again classified according to the number of carpels from which they arise. They are as follows—

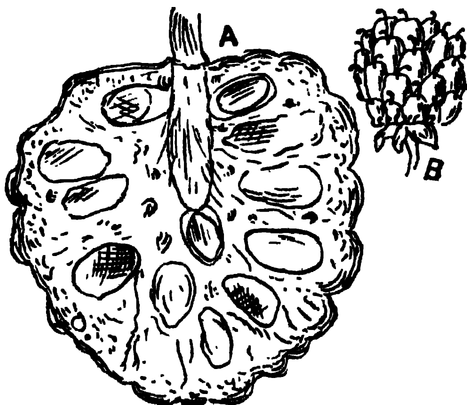


Fig. 107.
Aggregate fruits. A—*Ata*. B—*Strawberry*.

(1) **Monocarpellary** or consisting of one carpel.

(a) **Legume** is a superior fruit containing usually many seeds. It dehisces along both ventral and dorsal sutures. It is the characteristic type of fruits found in '*matar*' family as *bok*, *atusi*, *chinarbadam*, *aparajita*, etc.

(b) **Lomentum** is a legume, but it is alternately constricted and expanded in forms. Between any two constrictions there is a chamber containing a single seed.

Usually it dehisces transversely along the constrictions, as in the fruits of *babla*, *lajjabati*, *tentul*, *gila*, etc.

N. B. This term is sometimes loosely applied to other forms of transversely constricted fruits.

(c) **Follicle** is a superior fruit with one or more seeds. It dehisces along the ventral suture only, as *akanda*, *kurchi*, *malati*, etc., where the fruits arise in a pair from a single flower as the two ovaries are free.

(2) **Bicarpellary** or consisting of two carpels.

(a) **Siliqua** is a superior many-seeded fruit which

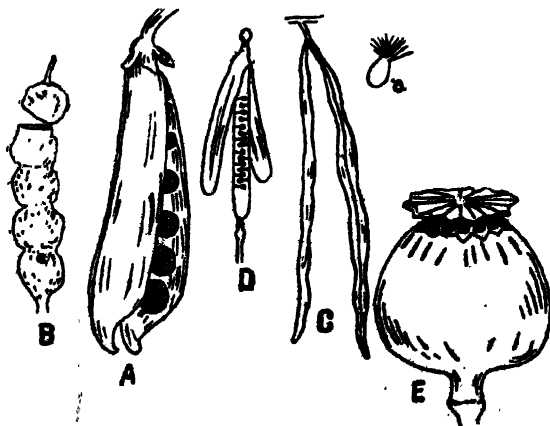


Fig. 108.
Dry dehiscent fruits. A—Legume. B—Lomentum. C—Follicle. D—Siliqua. E—Capsule.

dehisces from below upwards into two valves. The seeds remain attached to the persistent false partition-wall, called replum. The unilocular ovary becomes bilocular owing to the formation of this replum. The placentation of the ovary

is parietal. *Sarisha, mula* and other plants of the family produce this type of fruits.

(3) **Polycarpellary** or consisting of more than two carpels.

(a) **Capsule** is a superior, many-chambered and many-seeded fruit, which dehisces by pores. valves etc. The placentation of the ovary is usually axile. *Simul, dhanras* and other fruits of the family are good examples.

II. **Dry indehiscent fruits.** The pericarp usually remains in contact with the seed. It helps the seeds during their dispersal or during germination. The fruits are classified as follows :—

(I) **Monocarpellary**

(a) **Achene** is a superior, unilocular, and one-seeded fruit, the dry pericarp of which is separable from the seed, as in *ban palang, chhagalbati*. etc.



Fig. 109.
Caryopsis of *bhutta*

(b) **Caryopsis** agrees with the achene but the pericarp is fused inseparably with the testa of the seed, as found in the fruitlets of *dhan* family.

(2) **Bicarpellary.**

(a) **Cypsela** is an inferior, one-chambered and one-seeded fruit in which the persistent pappus calyx, forming a crown at the top, helps the dispersal of fruitlets by wind. The placentation of the ovary is basal. The fruitlets of *surja mukhi, kukur sonka* and other plants of the same family are good examples.

(3) Tricarpellary.

(a) **Nut** is a one-chambered and one-seeded fruit in which the pericarp is woody or leathery, as found in many *palms*, *paniphal*, etc.

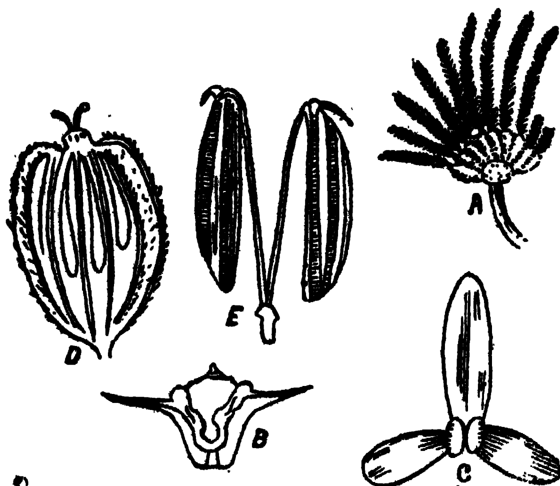


Fig. 110.

Dry indehiscent fruits. A—Achene of *chhagalbati*. B—Nut of *paniphal*. C—Samara of *madhobilata*. D—Cremocarp of *dhania*. E—Cremocarp, when dehiscing.

(4) Winged.

(a) **Samara** is a superior, one-seeded fruit, the pericarp of which develops in the form of wings required for the dispersal of seeds by wind, as found in *madhobilata*, *sal*, etc.

[illegible] **Dry schizocarpic fruits.** The pericarp breaks up [illegible] indehiscent or, in a few cases dehiscent, parts, each [illegible] a single seed.

(a) **Cremocarp** is an inferior, two-chambered and two-seeded fruit which splits up into two indehiscent parts, called **mericarps** attached to the common axis, called **carpophore,** as in the fruits of *dhania*, *mouri* family.

(b) **Regma** is a superior, three-chambered fruit which breaks up into three dehiscent chambers, called **cocci,** each containing a single seed, as found in *rerhi*, *amrul*, etc.

Fleshy fruits. The pericarp usually consists of three layers one of which at least must be fleshy.

(a) **Berry** is a fruit the whole pericarp of which is fleshy throughout, with many seeds, as found in *bagoon*, *peyara*, *angur*, *papya*, etc.



Fig. 111.
Pepo fruits of *tarmuz*.

(b) **Pepo** is an inferior, many-seeded fruit in which the epicarp is tough while the mesocarp and endocarp are fused to form a pulpy mass in which the seeds lie embedded.

The placentation of the ovary is parietal, as *kumro, lau, shasha, tarmuz*, etc.

(c) **Hesperidium** is a superior, several-seeded fruit in which the upper two layers of pericarp are fused to form a leathery rind of the fruit, while the endocarp forms the chambers from the inner walls of which many juicy cells appear. The placentation of the ovary is axile. All kinds of *nebu* are examples of this type of fruits.

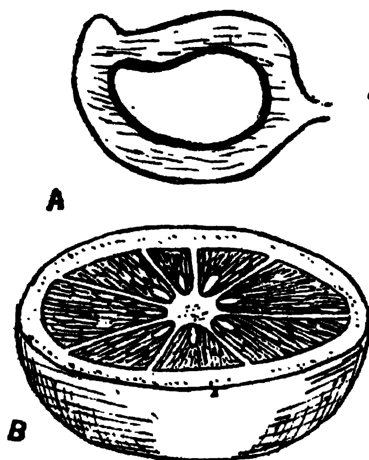


Fig. 112.
Fleshy fruits. A—Drupe of *am*. B—Hesperidium of *nebu*.

(d) **Drupe** is a superior, one or two-seeded fruit in which the pericarp is differentiated into three layers ; the epicarp is soft ; mesocarp is fleshy, fibrous and edible while the endocarp is very hard and stony. *Am, amrah, kul, peach*, etc. are good examples of this type.

B. Aggregate fruits.

They are formed from many free ovaries of separate carpels of a flower. The fruitlets are aggregated together on the thalamus. They remain separate, as in *champa. kantalichampa, padma* or they form a fused mass, as in *ata, nona*, etc.

C. Compound or Multiple fruits.

(a) **Sorosis** arises from a spike consisting of many small female flowers. The rachis, along with the ovaries and perianth of the flowers, develops simultaneously and becomes fleshy and fused into a single mass.

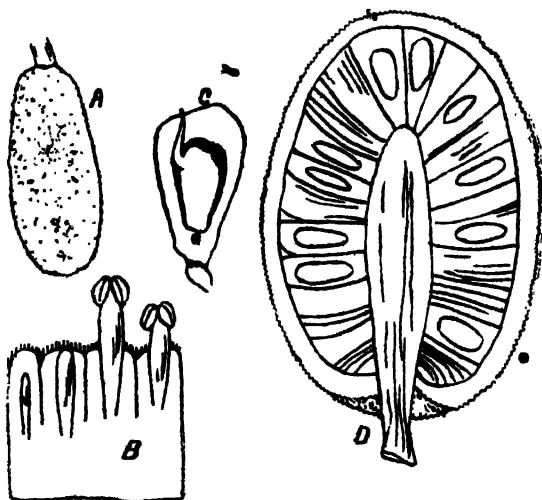


Fig. 113.
Sorosis of *kantal*. A—Young spike. B—Male flowers C—Female flower. D—Long. section of the fruit.

In *kantal*, the huge, fleshy and club-like body in the middle is the rachis on which are many fleshy chambers, each situated in the axil of a fleshy bract. In each chamber, the outer fleshey edible covering is the perianth. Just out side the single seed of each chamber there is a thin membrane which is the pericarp. The spinous projections of the fruit are the persistent stigmas of the flowers of the inflorescence, some of which become fertilised and fleshy while others remain unfertilised.

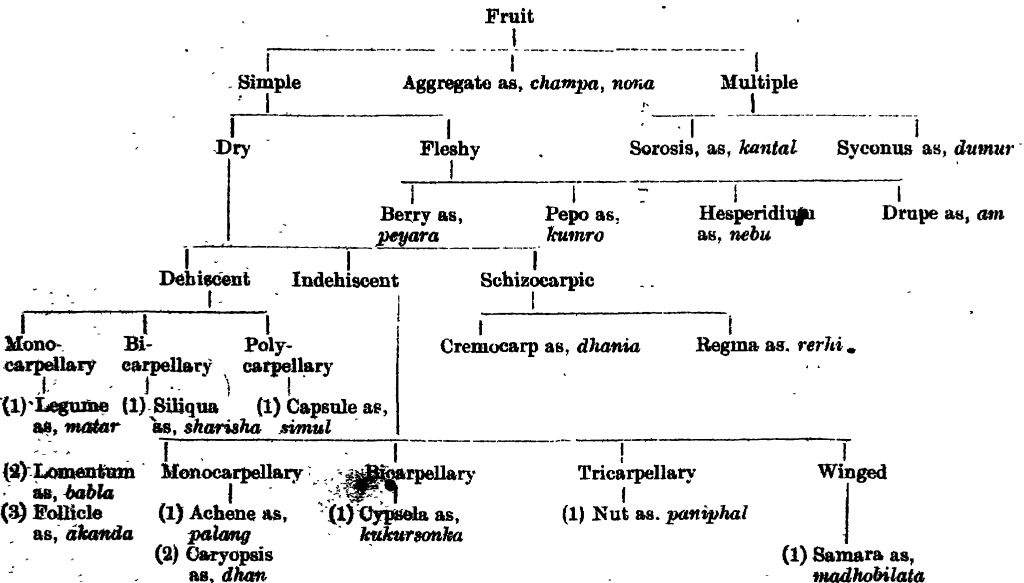
In *anaras*, another sorosis, the eyes on the fruit are the stigmas. The bracts are fleshy in their lower portions within the fruit, while their upper parts outside the fruit are leaf-like. The rachis is fleshy on its outer region but hard in the core. The edible part consists of fleshy portions of rachis, and bracts as well as perianths and pericarps all fused together. The rachis produces a cluster of leaves at the head of the fruit.

(b) **Syconus** arises from a hypanthodium of which the deep cup-shaped fleshy rachis contains many minute fruitlets, each having a pericarp. The rachis is the edible part of the fruit of *dumur*. Other examples of this type are *bot*, *aswatha* etc.

Edible parts of some common fruits.

	Fruits		Edible parts.
1.	*Am*	..	Mesocarp.
2.	*Nebu*	..	Juicy cells in the form of hairs appearing from the walls of endocarp and placenta.
3.	*Narikel*	..	Endosperm and the spongy ball of cotyledon.
4.	*Kantal*	..	Seeds and fleshy perianth.
5.	*Dumur*	..	Rachis.
6.	*Angur*	..	Pericarp.
7.	*Kola*	..	Endocarp.
8.	*Peyara*	..	Thalamus and pericarp.
9.	*Chalta*	..	Persistent fleshy sepals.
10.	*Dhan*	..	Endosperm.
11.	*Matar*	..	Cotyledons.
12.	*Tentul*	..	Inner layer of the pericarp.
13.	*Lichu*	..	Aril (outgrowth of the seed coat).
14.	*Anaras*	..	Rachis (outer portion), bracts (lower portion), perianth and pericarp.
15.	*Apel*	..	Thalamus.
16.	*Dalim*	..	Outer coats of the seeds.

Tabular summary of the classes of fruits.



Some common peculiar fruits :—

(1) *Khejoor* is a **berry** though it looks like a drupe. The outer thin skin is epicarp ; the mesocarp is sticky and edible. The stone is the seed and not endocarp which surrounds the stone as a thin membrane.

(2) *Narikel* is a **fibrous drupe** having the three well-differentiated layers which include the stone. The trilocular ovary is reduced to a **dry**, one-seeded, unilocular fruit. Just beneath the thin epicarp there is the fibrous mesocarp which surrounds the shell or endocarp. The brown layer covering the edible endosperm is the testa.

(3) *Tal* is a **drupe** with its stone as the endocarp. The seeds are two or three in number.

(4) *Kola* is a **berry** though the seeds are usually absent and the fruit arises from inferior ovary.

(5) *Nashpati* is called a **pome** : the edible part is formed by the fleshy hollow thalamus enclosing the ovary. *Apel* (apple) is another example of pome.

(6) *Lichu* is a **nut** ; the skin is formed by epicarp and mesocarp ; the endocarp forms a thin membrane covering the aril or edible part. (see seed).

Exercise IX

1. What is a fruit ? How would you distinguish between true fruit and false fruit ? Give a short account of the classification of the various kinds of fruits. Cite examples.—C. U. 1930, 1927, 1925, 1922, 1921, 1918, 1915.

2. Describe in botanical terms, the edible parts of the mango, the fig, the pine-apple, the guava, the lichi. the cocoanut and the moog—. C. U. 1921, 1919, 1915.

3. Compare the fruits of mango, brinjal and shim.—C. U. 1911.

CHAPTER X

SEEDS AND THEIR DISPERSION

Seed is the product of all changes taking place in the ovule induced by fertilisation. It is a ripened ovule, an integumented sac, in which the fusion of male and female cells has occurred.

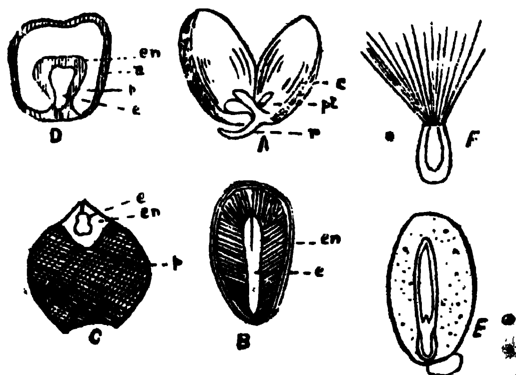


Fig. 114.

Seeds. A—Exalbuminous. c—cotyledon. pl—plumule. r—radicle. B—Albuminous. en—Endosperm. e—Embryo. C, D—Perispermic. p—Perisperm. E—*Rerhi* seed with caruncle. F—Comose seed of *Akanda*. a—Seed coat.

Let us study the changes that usually occur in the ovule during its conversion into seed. The **two integuments** are persistent. Undergoing some change and becoming fit for the protection of the embryo, they are converted into **testa** and **tegmen**. The **funicle** of the ovule forms the

stalk of the seed. The opening through the integuments or the **micropyle** is traced in the seed. As nucellus is usually wholly absorbed by the embryo during its development, the inner portion of the seed consists of only embryo, or in some cases, it is accompanied by a nutritive mass called **endosperm** (page 15). Thus, seeds may be **albuminous** or **exalbuminous** according to the presence or absence of **albumen** or endosperm.

Rarely, there are seeds where the nucellus is not completely absorbed. The portion of nucellus left behind forms another nutritive mass called **perisperm**. Where perisperm is present, the seeds usually have also endosperm in them. We find the following three types of seeds.

(1) **Ex-albuminous** seeds consisting of embryo and seed-coat.

(2) **Albuminous** seeds consisting of seed-coat, embryo and endosperm.

(3) **Perispermic** seeds consisting of seed-coat, embryo and perisperm. (Endosperm is usually present).

Ovule and seed compared

Let us trace the corresponding parts of an ovule when it is converted into a seed.

Ovule	**Seed**
1. Outer integument	1. Testa
2. Inner integument	2. Tegmen
3. Micropyle	3. Micropyle
4. Funicle	4. Stalk
5. Embryo-sac	5. Embryo and sometimes endosperm
6. Nucellus	6. Perisperm or absent

1. **Aril** or **arillus** is another seed-coat which grows occasionally from the base of the ovule and is loosely arranged on the seed. In *lichu*, *ans-phal*, etc., it is fleshy and edible and it surrounds the seed. In *uchhe*, the fleshy covering of the seed is also aril. In *jayphal*, it arises from the micropyle. The ridge-like outgrowth in *rerhi* seed on the testa is **caruncle.**



Fig. 115
Lichi fruits

2. **Comas** are tufts of hairs arising on the seed, as in the seeds of *akanda*, *shimool*, *kapas*, etc.

3. **Wing-like** outgrowths are sometimes developed on the seeds, as of *sajina*, *mahogany*, *begonia*, etc.

Dispersion of seeds : its need.

If seeds after their liberation from fruits be deposited on the soil directly under the plant, they can not find all the conditions favourable for germination. The light and the air are insufficient for them as they are shaded by the mother plant. The poor soil from which food materials have been to a great extent used up by the mother plant, can not provide them with food. So, most of the seedlings perish in the struggle under such unfavourable conditions.

If all the seedlings be allowed to die in this way, the species to which the seeds belong can not be maintained. Thus, in order to enable most of the seeds of a plant to propagate their species, wonderful provisions have been

made by nature to scatter them to such localities far away from their mother plant, that they can find the conditions for their growth suitable.

Agents for dispersal

Plants have no power of locomotion nor have the power of throwing their seeds always to a great distance. Thus, they are to depend on some agents for such dispersal. The agents are **wind**, **running water**, **animals**, **birds**, etc. Sometimes, they themselves adapt some mechanical contrivances in order to serve this purpose.

A. Dispersal by wind.

1. Seeds of *orchids* are very small and light so they can easily be carried away by wind.

2. Fruits or seeds with wing-like expansions are adapted specially for this purpose. *Sajina*, *muchkunda*, *parul*, *shal*, *madhobilata* are examples of this type.

3. Seeds with comas are carried away even by the gentlest breeze. *Akanda*, *karabi*, *simool*, *kapas* seeds are dispersed in this way. The persistent hairy styles of *chhagalbati* look like plumes. The fruitlets of *kukursonka*, *surjamukhi* are provided with a crown of persistent calyx looking like a parachute. This crown makes the fruitlets buoyant in the air. The hairy fruitlets of many *ghas* is a common observation in the meadows after the rainy season.

4. When the fruits dehisce partially at the apex or by means of pores or teeth, seeds come out of the fruits a few

at a time, when jerked out by a gust of wind. This is found in the fruits of *shealkanta*, *poppy*, *dhanros*, *dhutra etc.*

B. Dispersal by water.

Running water helps much in the dispersion of fruits of aquatic plants, as *padma*, *shaluk*, or plants growing on the river-bank or seashore, as *narikel*. These fruits possess

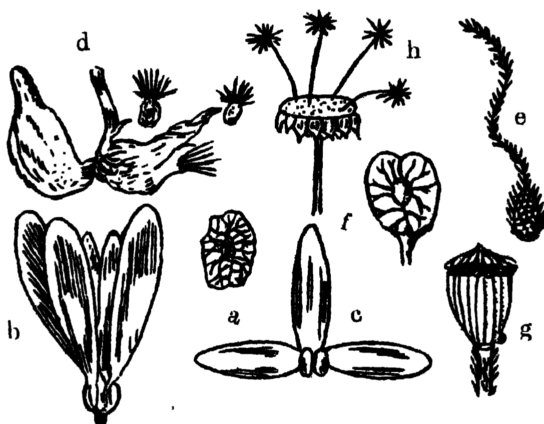


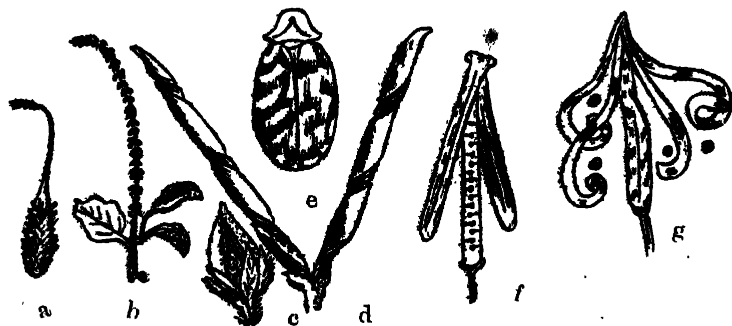
Fig. 116.

Wind-dispered seeds or fruits. a—*Orchid* seed. b—Fruit of *shal*. c—*Madhobilata* fruit. d—*Akanda* seeds coming out of the fruit. e—*Chhagalbati* fruit. f—*Kukursonka* fruitlets. g—*Poppy* fruit. h—*Elm* seed.

air spaces in any part of them, so that the light bodies can easily be drifted away in the current of water. In *padma*, the thalamus on which the fruitlets lie embedded is spongy and light.

C. Dispersal by animals or birds.

1. There are some fruits or seeds which are provided with hooks, spines or hairs. These may be persistent styles, stigmas or even bracts. They may adhere to the bodies of the grazing or passing animals, or to the clothings of men, and are thus transported to a great distance. These are found in *bagnakha*, *chorkanta*, *apang*, *bana*, etc. Sometimes the seeds are so sticky, as in *chita*, that they become easily attached to the fur of animals.



Fig, 117.
Seeds or fruits dispersed differently. a—*Bonokra*. b—*Apang*. c—*Amrul*. d—*Matar*. e—*Rerhi*. f—*Mula*. g—*Dhopti*.

2. Fleshy fruits, like *peyara*, *dumur*, *neem*, *bot*, *khejur*, *tal*, etc., are eaten by birds or animals. In some cases, their seeds are too hard to be crushed by the teeth of animals. The pulp of the fruits is digested but the seeds passing through the alimentary canal of animals are not injured and have thus the chance of germinating on a locality far from their mother plants.

3. Fruits, like *telakucha*, *makal*, etc., are highly attractive to the birds for their rich colour. The birds devour the luscious juice but reject the seeds.

4. In *angur*, all kinds of *nebu*, etc., the seeds are bitter or distasteful, so they are always thrown away while the fleshy portion of the fruits is taken.

5. Seeds of *reri*, have peculiar markings on them for which the birds take them as insects but throw them away to a great distance when found deceived. The red seeds of *champa* also deceive the birds in the same way.

6. Water-fouls, ducks, etc., visiting ponds after ponds in search of their food usually disseminate many sticky seeds of aquatic plants by carrying them in their muddy feet.

D. Dispersal by mechanical contrivance.

Fruits, like *dhopati*, when fully mature, burst with an elastic force to eject their seeds in all directions. The fruits of *dhundul* discharge their seeds with great force from their open mouth like shots from a pistol. Other fruits, like *amrul*, *sheuli*, act in the same way. Usually, the ejection takes place when the atmosphere is very dry. Legumes of *matar atusi*, etc., scatter their seeds mechanically.

E. Dispersal by human beings.

In the modern civilisation, people travelling from one climate to another may carry plants or parts of them, out of fancy or for economical purpose. For this reason, it is usually observed that a plant quite unknown to the climate suddenly grows up and thrives well. Sometimes, people help the migration without the knowledge of the seeds they carry.

Summary of Chapter X

1. Seed is the result of changes occuring in the ovule induced by fertilisation. Seed may be **albuminous**, **ex-albuminous** or **perispermic**. Usually a seed is covered with a coat which encloses the embryo and also endosperm, if it is present.

2. The outgrowths of seed-coat may be **arils**, **comas**, or **wings**.

3. Seeds can not get suitable conditions of germination and growth if they are placed directly under the mother plant ; hence thev are to be scattered.

4. The agents for dispersal are **wind**, **water**, **animals**, **birds** etc.

5. Wind-dispersed seeds may be small, winged, hairy, or may come out of fruits when jerked.

6. Water-dispersed seeds are usually helped by the presence of air spaces.

7. Seeds or fruits are dispersed by animals or birds (a) by clinging to their bodies ; (b) by the digestive process of their stomach ; (c) by their attractive colouration ; (d) by deceptive appearance ; (e) by being distasteful ; (f) by attaching themselves to the muddy feet of water-birds.

8. Seeds are dispersed by explosion. Human beings also distribute the seeds from one climate to another.

Exercise X

1. Describe from your own observations the various ways in which seeds are scattered. Of what importance is this dispersal to the species ?—C. U. 1927, 1911, 1910.

2. Describe the ways by which fruits and seeds are distributed with special reference to adaptive structures in them.—C. U., 1923.

PART II

HISTOLOGY

CHAPTER I

CELL

Up to the present, in our study of the various members of plants, we have only examined their structures from outside. Now apart from the external structure of the organs, we should know something of their internal structure. So far our naked eyes have been sufficient for the study of the external structures but to deal with the minute internal structures. we are to take the help of the microscope, an instrument, by which minute objects are highly magnified.

If a very thin slice or section, so thin as almost transparent, be taken from any part of a plant member and examined under the microscope, we find that it is divided up by a network of walls into numerous minute chambers of similar or different sizes and shapes. These compartments look very much like the cell of a beehive. It is for this similarity that the early anatomists applied the word 'cell' to the chambers.

In the year 1667 an Englishman, named Robert Hooke, first discovered cells in plants. He was a dealer in pictures of microscopic objects and his first picture concerning plants was that of a piece of bottle cork. Hooke's discovery was very soon followed by the works of two eminent men—Nehemiah Grew in England and Marcello Malpighi in Italy. They are regarded as the founders of Histology.

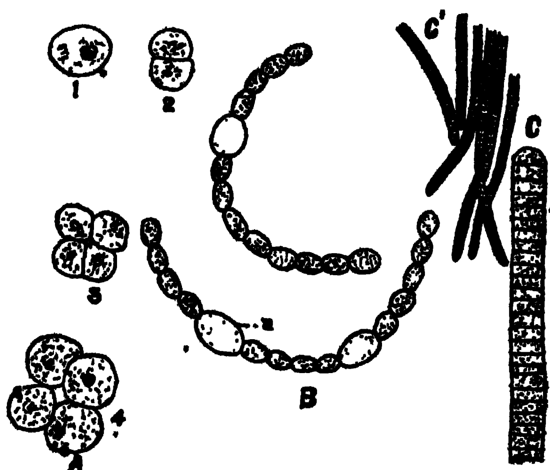


Fig 118

Different kinds of *shaola* as seen under the microscope.

Cells are the histological units of the plant structure. Just as a house, as a whole, is built up of many small separate bricks, so the whole body of a plant is composed of a number of definite parts which are themselves built up of tiny individual parts corresponding to the bricks of a house. This similarity does not extend far, as the tiny

parts of the plant are living and growing. Thus, every organ of the plant must be composed of those histological units which go to build up the body of that organ.

Parts of a typical cell.

If some green filaments of *Shaola* be taken out of water and examined under the low power of the microscope, they will be found to be composed of rows of cylindrical cells. Similarly, a thin layer of an onion scale may be examined under the microscope, when a large number of more or less

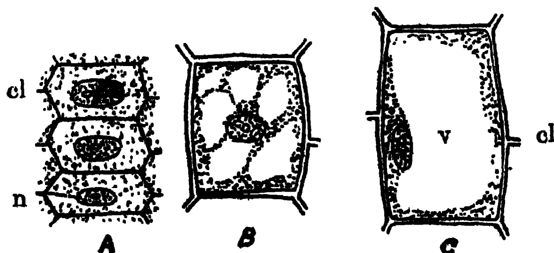


Fig. 119.

Parts of a cell. A—Protoplasm filling up the whole cavity of the cell. cl—Cell-wall. n—Nucleus. B—Vacuoles formed in the protoplasm. C—Protoplasm lining the cell wall ; Vacuoles coalesce to form one, v.

rectangular cells will be noticed. The walls of these cells are clearly visible, and the clear space, enclosed by the walls, is occupied by a semi-fluid jelly-like substance which being more or less transparent can not be ordinarily seen unless it is stained with any suitable reagent. This semi-fluid substance, found in every living cell, is called **protoplasm** and the boundary walls are known as **cell-walls.** If the onion scale be treated with iodine solution the protoplasm is stained yellow. Within the protoplasm

can be made out a small body more deeply stained than the surrounding protoplasm. This is called the **nucleus** of the cell. The protoplasm, the nucleus and the cell-wall are the three most important constituents of a living cell. Most of the cells are uni-nucleate, i.e., each of them contains a single nucleus. In lower plants, certain cells are multinucleate.

On examining sections, taken a little below the growing point, we find that the cells are somewhat larger and the whole cavity of a cell is not entirely filled up with proto-

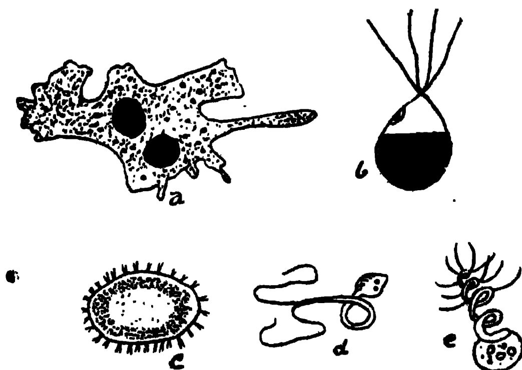


Fig. 120.

Naked cells of lower plants. a—Plasmodium. b—Reproductive cell of Ulothrix. c—Reproductive cell of Vaucheria. d—Male sexual cell of Moss. e—Male cell of Fern.

plasm but drops of water appear in it. This water containing soluble and insoluble substances in it, is called **cell-sap**. The spaces filled up with cell-sap are called **vacuoles**. As growth of the cells goes on, the several vacuoles of a cell coalesce, to form a single large cavity generally in the middle

of the cell containing cell-sap. Protoplasm, at this stage with its contained nucleus forming a layer lining the cell-wall internally, is called the **primordial utricle**.

Cells--living and dead.

The living substance or the protoplasm is usually bounded by a cell-wall. This is common in all the living parts of the plant. When a cell consists only of a mass of protoplasm not enclosed by any wall, the cell is **naked**. Naked cells are usually found in connection with the work of reproduction. Hence these are also called **reproductive cells**. Sexual cells, specially of the higher plants, are generally naked. Vegetative cells of the lowest order of the plants are, in some cases, naked.

When the protoplasm of an old cell vanishes, and there remains nothing within the cell-wall but air or water, the cell with its bare framework is called **dead**. Dead cells in plants, though apparently useless, usually serve some important functions. In cork or bark, the dead cells are protective. In wood or other harder parts of plants, the thick cell-walls of the dead cells discharge mechanical functions. Long tube-like dead cells, in the interior of plants, conduct raw food materials absorbed by the roots.

Unicellular and Multicellular plants.

In the study of lower plants, we shall find that the plant-body is usually composed of one or several similar cells. With one cell only, plants are unicellular. Plants are multicellular when many cells form the plant structure Higher plants are always multicellular. They consist of aggregations of cells varying in shape, size and functions.

PROTOPLASM

Composition of protoplasm.

This living matter of the cell is a highly complex substance. It consists of a mixture of various substances called, by chemists, **proteids** which are more or less similar in composition to the white of an egg. The proteids are composed of five elements,—**carbon**, **hydrogen**, **oxygen**, **nitrogen** and **sulphur**. An active protoplasm contains a large proportion of water besides the proteids. Protoplasm is incapable of serving any function unless it is permeated with water.

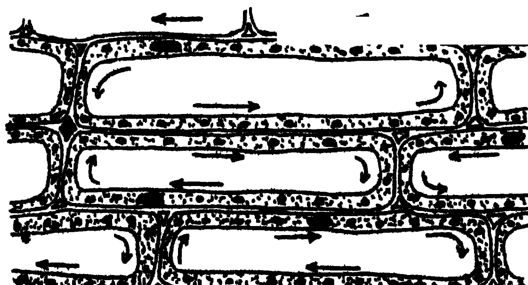


Fig 121.

Cells of *Patashaola* showing rotation of protoplasm in the cells

Functions of protoplasm.

Protoplasm is the seat of all the vital activities of a plant. So long the living substance is present, plants are capable of carrying on all their functions viz., absorption of food, digestion, growth, respiration, transpiration, reproduction, etc. Protoplasm is found to be inactive or dormant in seeds or spores during their resting period.

Protoplasm is a highly irritable substance. It is highly sensitive to external stimuli such as, heat, light, gravity, moisture, etc. It is simply due to this irritablity of protoplasm that roots grow towards those regions of soil where they can get water or salts dissolved in water. Other examples showing the irritable nature of protoplasm will be explained in the chapter on Physiology.

Movements of protoplasm.

Living protoplasm, in some cases, exhibits peculiar movements within the cell. These movements, manifested, are of different kinds in different plants.

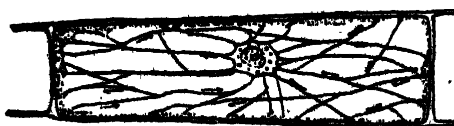


Fig. 122.

A cell of *kumro* hair showing circulation of protoplasm.

1. The reproductive cells of most of the lower plants are motile. The fine, long protoplasmic threads, called **cilia**, developed at their ends, help their movement in water or dew drops. This is called **ciliary movement** of protoplasm.

2. The **creeping movement** observed in the naked mass of the protoplasm of a *myxomycete* (Fungus), found on damp soil, in order to engulf its food is **amoeboid**.

3. The movement of protoplasm within the cell-wall, known as the **streaming movement**, is mostly observed in the living cells of higher plants. This is of two types—**rotation** and **circulation**. When the direction of movement in the cell is constant, it is **rotation**, as found in the

cells of *Pataskhaola* and many other aquatic plants. But when the direction is not constant but always changing within the cells, it is called **circulation**. This is found in the hairs of *Kumra* stem, where the primordial utricle is found to be connected by the threads of protoplasm which traverse the vacuole and meet in the centre where lies the nucleus. The moving granules run up one thread and down another. Rotation is generally observed in water plants while circulation is more usual in land plants.

Tests for protoplasm.

1. An active protoplasm gives an alkaline reaction.
2. It coagulates when treated with alcohol or acids of any strength.
3. **Iodine** stains it brownish **yeollw**.
4. It is soluble in dilute caustic potash and in Eau-de-Javelle.
5. Treated with acid nitrate of mercury, called Millon's reagent, it becomes brick red in colour.
6. When coagulated, it absorbs colouring matters as of eosin, safranin, carmine, etc.

Parts of protoplasm.

Cytoplasm, nucleus and **plastids** are the three differentiated parts which form collectively the living substance of a typical vegetable cell.

A. **Cytoplasm**—It is the semi-fluid granular substance present within the cell. It is the ground substance in which nucleus and plastids lie embedded. In a naked cell, it may be differentiated into two layers—the outer or protective is **ectoplasm** and the inner is **endoplasm**. Usually, when

the naked cell is to serve its functions in water, the ectoplasm projects and forms **cilia** which lash in water and act like the oars of a boat.

In a walled cell, the thin outer layer of cytoplasm, being free from granules, is transparent in appearance. This is **ectoplasm**. The inner layer is granular and turbid in appearance. This is **endoplasm.** Nucleus and plastids always lie embedded within it. When a cell grows and vacuoles appear within it, another layer of cytoplasm may be differentiated surrounding the vacuoles. This is **tonoplasm.**

B. **Nucleus**—It is the condensed body of cytoplasm. It controls and directs all the activities of the cell. It takes a predominant part in reproductive functions and in cell-divisions. It is honeycomb-like in appearance and usually oval in form. It consists of the following parts :—

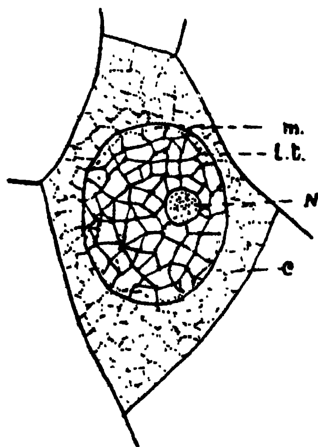


Fig. 123.
Resting nucleus with its parts. m—Membrane. l.t.—Linin threads. N—Nucleolus. c—Cytoplasm

1. **Nuclear membrane** or the layer which surrounds the main body of the nucleus.

2. **Nucleo-hyaloplasm** or the jelly-like ground substance within the membrane.

3. **Linin threads** are colourless hyaline threads lying entangled in the hyaloplasm forming a net-work.

4. **Chromatin granules** are numerous minute bodies embedded in the threads.

5. **Nucleoli** are one or more granular bodies in the net-work.

6. **Nuclear sap-cavities** are numerous cavities filled with sap.

New nucleus in the cell is formed not out of the cytoplasmic substance but by the division of old nucleus.

C. **Plastids**.

Plastids are also differentiated portions of protoplasm lying in the substance of cytoplasm. Like the nucleus, they are not formed from the cytoplasm but by the division of the original plastids. They are not present in all the cells. As a rule, they are absent in Fungi. Each plastid has a clear semi--fluid ground substance in which there is a net-work of proteid threads.

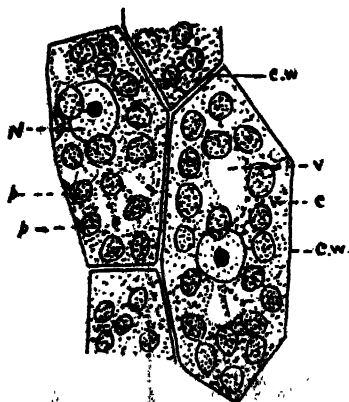


Fig. 124.
Chloroplasts in cells. cw—Cell-wall. v.—Vacuole. c—Cyto-plasm. N—Nucleus. p—plastids.

There are three kinds of plastids—**chloroplastids**, **chromoplastids**- and **leucoplastids** of which the first two are coloured and the last colourless.

(a) **Chloroplastids** or **chloroplasts** are green coloured ids found in all the green parts of plants. In cells of plastids are colourless. When exposed to the light, colourless plastids in the cells of some parts of plants as

leaves, young stems, etc., develop in them the green colouring matter called **chlorophyll**. For this reason, the chloroplasts are also called **chlorophyll corpuscles**. The ground substance of the plastids develops oily drops in which the green pigments are dissolved. Though chloroplasts are usually oval in form; there are other forms of them. In *Spirogyra*, an Alga, the chloroplasts are in the form of spiral bands.

When a plant is allowed to grow in darkness, the plastids develop a yellow colouring matter, called **etiolin** in place of chlorophyll, so the plant becomes pale yellow in colour. Again, a green plant soon loses its green colour when allowed to remain in darkness for several days together, but when brought to light, the plant may regain its normal green colour.

(b) **Chromoplastids** or **chromoplasts** are those plastids which are coloured other than green. The rich colouration of many floral leaves, some fruits as, *makal*, *telakucha* and some roots as, *gajar*, *beet*, etc., is due to the presence of chromoplasts in the cells. They take part in the formation of carbohydrates and may attract pollinating and seed dispersing agents. They are sometimes formed from chloroplasts, by the decomposition of chlorophyll. Like chloroplasts they may also be formed directly from leucoplasts when exposed to light.

Chloroplasts and chromoplasts are thus the plastids which bear in them the pigments, hence they are known as **chromatophores** or colour-bearers.

(c) **Leucoplastids** or **leucoplasts** are those plastids which are not coloured as the pigments do not appear in

them. They are found in the cells of the underground stems and other portions of plants not exposed to light. When exposed to light, they have the property of being converted into chromoplasts or chloroplasts under different conditions. They are known as **starch builders** as their important function is to produce starch grains out of the sugar solution present in the cells in the dark regions of plants.

Vacuoles—their formation.

Vacuoles, we know before, are cavities developed within the cytoplasm of a cell. These cavities are usually full of sap which contains various substances, some of which are soluble in water while others being insoluble remain floating in water. Some of them are organic, while others are inorganic. All of them are on their way to be formed by the active protoplasm or have already been formed.

When a living young cell goes on growing, growth at first affects the elastic cell-wall which begins to distend. However distended the wall is, protoplasm always remains in close touch with it. But the rate of the increase of the protoplasmic matter is never in proportion to the distention of the wall during growth. Consequently cavities are formed within the cytoplasmic mass. These cavities or vacuoles are soon filled up with water which gradually contains many organic and inorganic substances in solution, such as sugars, acids, salts, etc. In a rapidly growing cell, when all the vacuoles combine to form a large cavity, it exerts a pressure on the protoplasm which consequently becomes a thin layer lining the cell wall.

Summary of Chapter I

1. Cells—cells are the histological units of the plant structures. All parts of plants are built up of these microscopic elements called **cells.**

2. Parts of a cell—a living cell consists of **cell-wall, protoplasm** and **nucleus**.

3. Living and dead cells—Living cells without any wall are called naked. With a wall, the cell is called walled. Dead cells are devoid of protoplasm. They serve three functions—(1) They protect the inner living cells of the plant ; (2) they give rigidity to the plants ; (3) they conduct food solution.

4. Protoplasm consists of three parts—**cytoplasm, nucleus** and **plastids**. It is composed of carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. Protoplasm serves all the vital functions of the plant. It is usually irritable. It can rotate or circulate It shows other kinds of movements—ciliary and amoeboid.

5. Plastids are of three kinds -(1) **Chloroplasts** or green ; (2) **chromoplasts** or other than green ; (3) **leucoplasts** or colourless.

6. Formation of vacuoles—when cell-walls distend during growth, protoplasm, lying attached to the distended wall but failing to increase its substance, rapidly develops vacuoles in its body.

Exercise I

1. What is a cell ? Describe a typical vegetative cell and give a short account of the functions of the several parts. -C. U. 1924, 1921.

2. What is protoplasm ? Where it is found in plants and what are its functions ? How do you test for it ?—C. U. 1911.

3. Describe Nucleus. —C. U. 1921, 1910.

CHAPTER II

CELL-CONTENTS

Protoplasm, with its differentiated parts, is the living content of a cell. Besides protoplasm, other substances, either solid or liquid, are present in the cytoplasm or in the vacuoles. They are the non-living contents of the cell.

These non-living contents are of varied nature. Some are soluble, some insoluble ; some are to be utilised by plants, while some are meant for storage ; some are organic, some inorganic ; some are useful for plant lives and some are waste products ; some are acids, some are the salts of the acids, while others are colouring matters ; some are carbohydrates, some oils, some proteids, while others are in the form of crystals.

They are principally classified into solid and liquid. The chief solid contents are (1) **starch grains**, (2) **aleurone grains**, (3) **inorganic crystals**. Other solid contents are cellulose, resin, gum, etc.

The liquid contents are (1) **sugars** which are usually in solution, (2) **fats** and **oils**, (3) **acids**, (4) **colouring matters**, etc.

A. **Solid contents.**

(1) **Starch grains**—They are the important food matters found in most parts of plants. They are highly useful during growth, so they are, as a rule, present in the growing apices of plants. They occur both in the dark as well as in the lighted regions of plants. They are absent in Fungi, total parasites, etc. They are all carbohydrates, that is, chemically they consist of the three elements—carbon, hydrogen and oxygen, of which the last two are in the proportion of two to one, as in water (H_2O). The chemical formula for this organic substance is expressed in ($C_6H_{10}O_5$)$_n$ where n is indefinite. The substance of a grain is composed of cellulose, granulose and water.

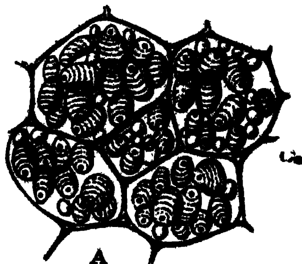


Fig. 125.
Starch in the cells of *potato* tuber.

Starch grains are mainly of two types—(a) **assimilatory**, or those which are formed in the green parts of plants exposed to light through the agency of chloroplasts, (b) **reserve** or those which are formed in the dark, deep-seated portions of plants due to the work of leucoplasts.

Assimilatory grains first of all appear in the chloroplasts of the green cells of leaves, stems and other organs in the form of minute granules at the expense of the sugar produced by the constructive activity of the chlorophyll and the protoplasm. They are the direct products of assimilation in the green parts in presence of light. They are unstable bodies, as they very soon undergo a change due

to the action of a ferment, known as **diastase**, when they are again converted into sugar.

Reserve grains are larger bodies formed in the internal dark parts of plants, when the reconverted sugar of the assimilatory grains is transported there. The sugar received by the leucoplasts is transformed into stable granules.

The formation of a grain first starts with its organic centre, called **hilum**, round which the grain grows. Leucoplasts go on depositing new materials on the hilum in the form of successive layers, the denser of which alternate

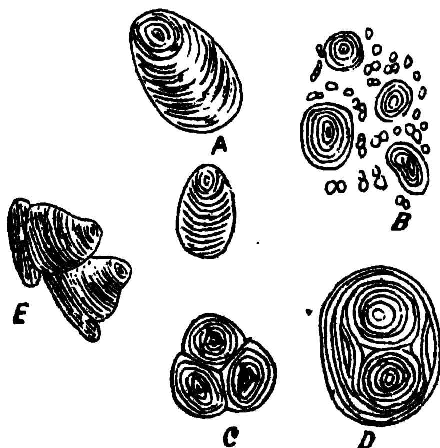


Fig. 126.

Forms of starch grains. A—Excentric grain. B—Concentric grain. C—Compound grain. D—Half-compound grain. E—Starch formed by the activity of leucoplasts.

regularly with the less dense ones. When seen under the microscope, fine refractive lines can be noticed on the wall, arranged in succession. These are the **lines of stratification** of a grain. The alternation of the lines is due to the

presence of varying amount of water in the grain, the maximum amount being at the hilum.

According to the arrangement of the stratified lines a grain may be **concentric** or **excentric**. When the lines are concentrically placed with hilum in the centre, it is **concentric**, as in the seeds of cereals (*job*, *gom*, *dhan* etc). When the hilum is at one side of the grain and most of the lines are placed outside presenting the appearance of an oyster shell, it is **excentric**. This form is found in underground stems, as *alu*, *kachu*, etc., aerial stems as of *gulancha*, most of the roots and seeds (excepting the seeds of cereals).

Reserve grains are either **simple** or **compound**. When the grains are all separately placed within the cells, they are all **simple**. But when the grains instead of remaining separate cohere to form a single body during development, they are **compound**, as in *dhan*, *job*, etc. Again, when several separate grains fuse together and the whole mass is surrounded by a few common layers, the grains are **half-compound**. These three forms may be present in the cells of the same organ, as in the tuber of *alu*.

Starch grains may be round, as in *matar* ; egg-shaped, as in *alu* ; dumb-bell shaped, as in *mansa*, *bharenda*, etc.

Tests—1. Starch is insoluble in alcohol and cold water, but when boiled with water, it is partly soluble and forms a paste. At high temperature, the pasty mass dissolves after it is converted into a kind of sugar.

2. **Iodine solution** stains starch grains **blue or violet.** The colour is destroyed by strong alcohol or on heating.

3. When treated with **potash solution**, starch at first swells up and then dissolves.

2. **Aleurone grains** or **proteid grains** or simply **proteids** or **proteins**—They are the important reserve food matters found abundantly in many seeds, as *matar*, *gom*, *rerhi*, *tishi*, etc. They are small and granular in seeds with starch, but large in seeds with oil. Besides carbon,



Fig. 127.
Aleurone grain. A—Section of the cotyledon of *matar* seed showing grains. b—Aleurone grains. a—Starch grains (bigger). B—Section of the endosperm of *rerhi* seed. a—Aleurone grain. b—Crystalloid. c—Globoid.

hydrogen and oxygen there is also nitrogen in the composition; hence these grains are also known as **albumens**. They are formed by the condensation of albumen when that is richly present in vacuoles. Crystals of proteid bodies, called **crystalloids**, are formed during the time of condensation.

The minute forms are usually simple, that is, they have no inclusions in them, as in *matar* seed, where in the section of the cotyledon two kinds of grains are found. When treated with iodine solution, some of the grains are stained blue and others yellow. The large, blue, concentric grains are of

starch while the small, yellow grains are of proteids. In *gom*, the grains, found in the cells of the outer layer of seeds, are small.

The larger forms, as found in the seeds of *rerhi*, *tishi*, etc., have two inclusions in them—(a) one or more **crystalloids** or crystal-like bodies occupying the major portion of the grain, and (b) **globoid** or a round body formed of the double phosphates of calcium and magnesium.

Tests—Aleurone grains are insoluble in alcohol but partly soluble in water. As protoplasm is composed of

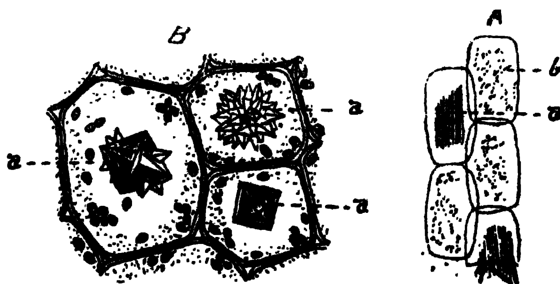


Fig. 128.

Crystals of calcium oxalate. A—cells of *kochu* stem. a—Acicular raphides. b—Mucilaginous cell. B—Cells of *onion* bulb. a—Sphaeraphides.

proteids, the chemical reaction of these grains is the same as that of protoplasm. Thus **iodine** solution stains the grains **yellow** and **potash** solution dissolves them.

3. Mineral Crystals.

(a) **Crystals of calcium oxalate—Raphides.**—They are found mostly in monocot plants, specially aquatics. When needle-like in form, the crystals are **acicular**, as in

kachu, *ol*. They protect the plants from the attacks of snails, slugs, etc. When the crystals are round, angular or star-shaped, they are **sphaeraphides** as in *pjaj*, *beet*, etc.

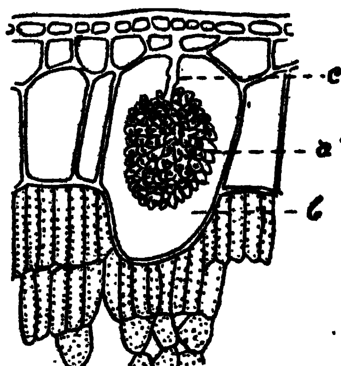


Fig. 129.
Crystals of calcium carbonate in the epidermal cells of *aswatha* leaf. a—Cystolith. b—Big cell. c—Cellulose projection.

(b) **Crystals of calcium carbonate—Cystoliths.**—These are found in the big epidermal cells of the leaves of *bot* family in the form of minute grape bunch supported on a short stalk which is a cellulose projection inside the cavities of the cells. The crystals are aggregated in each cell to form the bunch called **cystolith**.

Tests—The chemical reagents, used for distinguishing the two kinds of crystals are **hydrochloric acid** and **acetic acid.** Both the acids dissolve the cystoliths with the evolution of carbon dioxide gas. Oxalate crystals are dissolved in hydrochloric acid but not in acetic acid.

B. Liquid contents—

(1) Sugars

Various kinds of sugars are found in solution in the cell-sap. Of these, **cane-sugar** and **grape-sugar** are common. Cane-sugar is found in the stems of *ak*, *khejoor*, in the roots of *beet* etc., and grape-sugar is found in *angur*.

Inulin is another kind of sugar in solution stored up as reserve food matter in the roots of *surjamukhi* and other plants of the family. In chemical composition, it agrees with starch. It precipitates in alcohol in the form of crystals.

(2) **Fats and Oils**

Oils are of two kinds—(a) **Fixed oils or fats** and (b) **volatile or ethereal oils.**

Fixed oils are usually found in the protoplasm of the cells of the several seeds, as of *narikel*, *sarisha*, *rerhi* etc., in the form of drops. They are reserve food matters to be utilised during germination when they are converted into sugar. They contain no nitrogen in the composition but only carbon, hydrogen and oxygen.

Volatile oils are waste products secreted by the glands. They are not reserve food matters. The agreeable fragrance of flowers and the aromatic smell of some stems or leaves, as those of *camphor*, *pudina*, *tulsi*, etc., are all due to the presence of such oils in them.

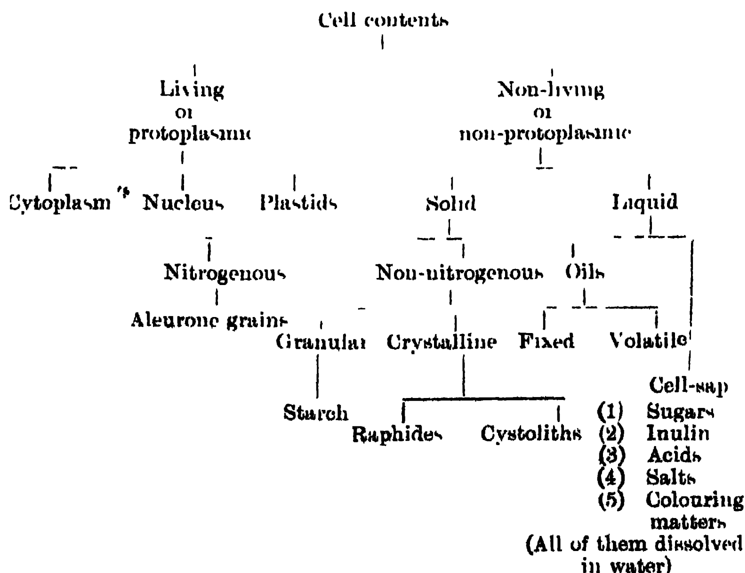
The floral perfume is for the attraction of pollinating insects, and the odour in leaves or stems is for scaring away injurious insects.

Tests—When treated with **osmic acid,** oils stain black. They are turned red with **alkana** solution. The two kinds of oils can be distinguished by putting drops of them on a piece of paper. Volatile oils leave no mark on the paper due to their volatility. They are also soluble in alcohol which can not dissolve fixed oils except castor oil.

Besides the above, there are other contents in the cells. Many acids are in solution in the cell sap. The tartaric acid in *tentul*, oxalic acid in *amrul*, citric acid in *nebu*,

malic acid in *am* are well-known acid contents. Formic acid is found in the hairs of *bichuti* while tannic acid is found in the plants of *babla*, *khayer*, etc. Nitrates, sulphates, chlorides, etc., are sometimes present in the cell-sap. Date seed contains cellulose as a reserve food. Pine contains resins ; India-rubber plants contain caoutchouc. There are also alkaloids present in some plants. Thus, tobacco contains nicotine, poppy morphine, cinchona quinine, and tea theine, etc. In some cases, colouring matters appear in the cell-sap.

Tabular summary of the cell contents.



Exercise II

1. State what you know of the various contents of a growing cell ? – C. U. 1926, 1918, 1909.

2. How would you recognise under the microscope the following :— starch, sugar, aleurone grains, calcium carbonate and calcium oxalate ?—C. U. 1922, 1918, 1911, 1909.

3. In which of the organs of plants is starch found ? Describe fully the appearance of starch grains as revealed by the microscope. —C. U. 1913, 1909.

4. What is the use of the oil that we find at times in plants and where do we chiefly find it ?

5. Describe fully the method you would adopt to demonstrate microchemically the presence of aleurone grains in vegetable cells. Describe the grains.—C. U. 1930, 1910.

6. What are raphides and cystoliths ? Where do you find them ? —C. U. 1929.

CHAPTER III

CELL-WALL

Cell-wall substance.

Cell-wall consists of a substance called **cellulose**, which is secreted by the protoplasm. It is very elastic and increases in thickness and area due to the activity of protoplasm. An active protoplasm forms the cell-wall, adds to its substance during the life of the cell and moulds it in such a way as to make it fit for the special functions which a cell is to perform.

Though apparently the cell-walls are the partitions between the cells they do not disturb their communication as the protoplasm of one cell is actually in connection with that of another by means of very delicate fine threads which pass through the different sides of the cell-walls.

Composition and property of cellulose.

Cellulose is a carbohydrate consisting of carbon, hydrogen and oxygen. The composition is thus the same as that of starch but the properties are different as the elements are differently arranged in the two. Cellulose is permeable to water and can hold much water in it.

Test for cellulose.

(1) Most of the thin-walled cells, as those of cotton, *shola*, etc., have their walls made up of cellulose. When treated with **iodine solution**, the walls turn yellow but

after treatment with **sulphuric acid**, iodine colours the walls **blue** This is the best test for cellulose.

(2) When treated with **chloro-zinc-iodine**, the walls swell up and turn **blue**.

Growth and thickening of the cell-wall.

The growth in thickness of the cell-wall may be by **apposition** and by **intussusception**. By apposition, the protoplasm secretes particles of cellulose which are deposited in successive layers on the inner surface of the cell-wall. In this way the cell-wall becomes gradually thicker. By intussusception, the new matters which are secreted by the protoplasm are pushed in between the particles of the original cell-wall with the result that the cell-wall increases in surface-extent.

The growth of a cell may be uniform or localised, when it grows in size. With uniform growth, the cell is usually roundish in form. When the growth is localised to the two points opposite to each other, the resulting cell becomes an elongated one. Similarly, when the growth is confined to three or four points of the cell-wall, the cell, after growth, assumes the form of a star-shaped body. Thus, when the growth is localised, different forms of cells, viz. oval, stellate or star-shaped, polygonal, etc., are produced.

As a general rule, growth in thickness does not occur till the cell has reached its full size. Uniform thickening over the whole surface of the cell-wall is rarely met with. With unequal thickenings projecting inwardly various markings appear on the inner surface of the cell-walls. These are specially observed in the wood elements of plants. Thus when the thickenings occur in a spiral line or in separate

transverse rings, they are called **spiral** or **annular**. Thickening is **reticulate,** when it is in the form of a network or is placed irregularly on the wall. When the whole inner surface of the wall is thickened excepting many isolated unthickened spaces called **pits,** the thickening is

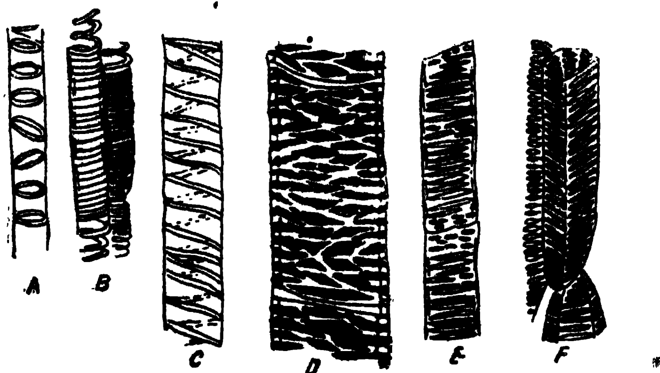


Fig. 130.
Vessels. A—Annular. B, C—Spiral. D—Reticulate. E, F—Scalariform.

pitted. When the thickenings look like the rungs of a ladder, they are called **scalariform.** The wood elements called **vessels** are named according to the different types of thickenings formed on the inner surface of their walls. They are thus termed **spiral, annular, pitted,** etc.

In **pitted vessels,** the pits formed may be **simple** or **bordered.** When bordered, each circular unthickened area is over-arched at the edge by a circular thickened rim in the form of a dome which becomes more and more narrow towards the centre of the cell when thickenings are deposited layer after layer surrounding the pit. In the same way, another such pit is formed at exactly the same point on

the other side of the wall. The thin area of the wall is slightly thickened in the middle called **torus**.

Usually, thickenings are laid down on the two sides of a wall. When three or four cells, with thickenings, meet, the much thickened middle space is known as **middle**

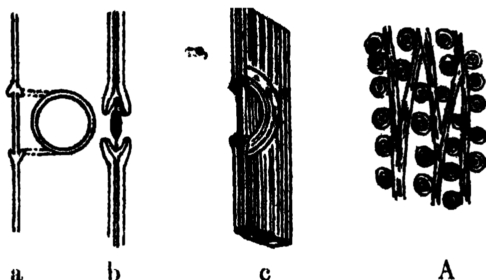


Fig. 131.

A—Bordered pits of tracheides. a—Pit in the young stage with unthickened cell-wall. b—Older stage showing the membrane with torus in the middle. c—Half-faced view showing the position of the middle membrane.

lamella. Sometimes, walls become so thickened internally that the cell-cavities can not easily be distinguished.

Chemical alteration of cell-wall.

When the cells become mature, not only it grows in thickness, but in some cases, the cell-wall substance becomes modified by undergoing some changes in it. The modifications of cellulose are **lignin**, **cutin**, **suberin** and **mucilage**.

(a) **Lignin** is present in the walls of all hard elements of wood and sclerenchyma. The lignified walls are not only hard but slightly elastic. Lignin gives strength and rigidity to the walls. It is permeable to water which it can not retain much in its substance.

Tests for lignin.

1. With **aniline sulphate** solution, lignified walls turn golden **yellow**.

2. With iodine solution and sulphuric acid, the walls are stained yellow and swell up.

3. With **chlor-zinc-iodine**, the walls stain **yellow**, and not blue.

4. The walls dissolve or in **Eau-de-Javelle**.

(b) **Cutin** is present on the external walls of epidermis or the outermost layer of cells of stems, leaves, etc. The cuticularised walls of epidermis form a membrane called **cuticle** which is elastic and almost impermeable to water. The cuticle protects the inner layers from excessive evaporation and makes the epidermis firm.

Tests for cutin.

1. It resists the action of sulphuric acid.

2. It turns yellow when treated with sulphuric acid and iodine solution.

3. With **chlor-zinc-iodine** the walls stain **brown**.

4. Cutin dissolves in boiling alcoholic **potash.**

(c) **Suberin** is present in the walls of corky cells, pollen grains, etc. Chemically, it has the same properties as those of cutin. Cutin withstands better the action of caustic potash.

(d) **Mucilage** is present in the cell-walls of the coat of several seeds and nutlets as *tisi*, *esabgul*, *topemari*, etc., as a dry substance which when brought in contact with water, absorbs large amount of it, swells up and becomes pasty. This power of absorption and retention of water is highly useful to those seeds during their germination.

(3) Impregnation of cell-wall.

Some mineral salts are sometimes deposited into the body of the cell-wall. Silica, calcium carbonate, calcium oxalate are the common salts which become impregnated into the cell-walls and make them hardened. The cell-walls of the epidermis of many grasses, *bans*, *ak*, etc. have a large amount of silica in them.

Intercellular spaces and cavities.

Cells, in the growing regions, are closely attached to each other. Gradually, when cells begin to grow and assume different forms in accordance with the different functions they are to perform, spaces appear at the points of junction of a number of cells. These spaces containing air or other gases are called **intercellular spaces.** They are usually big in size in the leaves where they form respiratory cavities. They are present in most of the water plants in which they being filled with air serve to give lightness to the plant thereby making them float easily on water. They are continuous in the plant-system, thus rendering the passage of gases and vapour easy.

Sometimes cavities are formed in the interior of plants or in the middle of many stems. There are two methods of such formation. They may arise **schizogenously** when the common walls of cells split apart to form cavities during the cell-growth, as found in the resin or mucilage ducts of *pine*, *sajina*, etc. Cavities may also be developed **lysigenously** by the complete disorganisation of certain cells, as found in the hollow stems of *dhania*, *mouri*, etc. and in the oil ducts of *nebu*.

Summary of Chapter III

1. Cellulose is the cell-wall substance of ordinary cells. It is elastic and permeable to water. It stains violet when the cell-wall is treated with iodine solution and sulphuric acid.

2. There are two methods of the growth of the cell-wall—apposition and intussusception. The growth may be uniform or localised. Growth in thickness is not also uniform. Due to unequal thickenings, vessels may be **spiral, annular, reticulate, pitted** and **scalariform.** The pitted vessels may have pits—simple or **bordered**

3. Cell-walls may be modified chemically. The modifications are **lignin, cutin, suberin,** and **mucilage.** Lignin occurs in woody elements, cutin in epidermis, suberin in cork, and mucilage in several seeds.

4. Intercellular spaces are cavities formed between the cells. Other cavities are formed in the plants either **schizogenously** or **lysigenously.**

Exercise III

1. What is cellulose ? Where it is found in plants ? What are its functions ? How do you test for it ?—C. U. 1931.

2. How does cellulose differ from lignin ? Give examples of lignified structures in plants. Where are they normally found ? C. U. 1928.

3. You are supplied with a piece of pith or shola and asked to examine it under the microscope in order to find out if it contains any cellulose. Describe in detail the method you would adopt.—C.U. 1924.

4. How do you test for mucilage ?—C. U. 1910.

CHAPTER IV

NUCLEAR DIVISION AND CELL FORMATION

The division of the nucleus is either direct or indirect.

(1) **Direct or amitotic division** is also called **fragmentation**. The nucleus divides by simple constriction, when the resulting numerous nuclei are usually of different sizes. This is a quicker process and occurs as a result of excessive nutrition in nuclei when there is rapid growth or frequent replacement of cells. Examples of this division are found in the long, old internodal cells of some lower plants, as *Chara*. This is not followed by cell-division.

(2) **Indirect division or Karyokinesis**—The nucleus passes through a complicated series of changes when they are followed by cell-division. Karyokinesis occurs in two ways—(i) **Mitosis** or the vegetative method and (ii) **meiosis** or the reproductive method.

(i) **Mitosis**—This process takes place in four stages :—

(a) **Prophase**.—The chromatin network becomes separated into a number of short and thick filaments called **chromosomes**. For each species, the number of chromosomes is practically constant and they are supposed to inherit all the characters of the species. Each chromosome is longitudinally split up into two equal halves which move away from each other in two opposite directions.

(b) **Metaphase**.—In the cytoplasm, immediately surrounding the nuclear cavity, extremely fine cytoplasmic

fibres appearing from the two opposite points or poles and penetrating into the nuclear cavity produce a thick tangled layer in the form of a spindle called **nuclear spindle**. At this stage, the nuclear membrane and the nucleoli disappear.

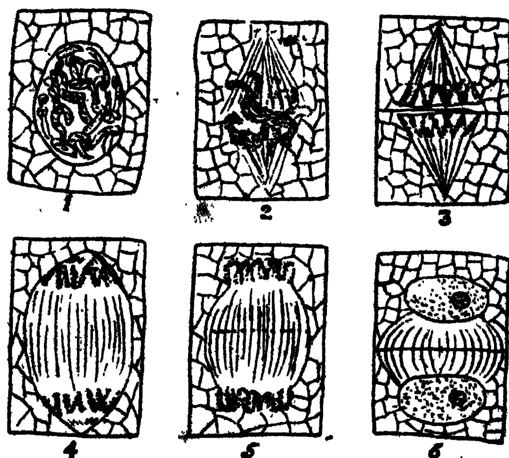


Fig. 132.

Karyokinesis, 1. Nucleus just at the time of division. 2. Network is divided into chromosomes and nuclear spindle is formed. 3. Chromosomes attached to the traction-fibres which draw them to the opposite poles. 4. Half the number of chromosomes reaches each pole. 5. Chromosomes fused at their ends and small granules appearing in the equator. 6. Cell divided into two, each with a new nucleus.

Some of the fibres, called **traction-fibres**, become closely attached to the chromosomes arranged in the middle of the form **equatorial plate**. The other fibres run freely from pole to pole.

(c) **Anaphase**—Due to the contraction of the traction-fibres the chromosomes begin to move towards the opposite poles of the spindle. Half of each chromosome, with its apex attached to the fibre and directed to the pole, is drawn to one pole while the other half to the other pole.

(d) **Telophase**—The ends of the chromosomes at each pole fuse to form a single, long filament which gradually becomes thin and much entangled, as in the resting nucleus. The nucleoli, as well as, the nuclear membrane appear again. In the mean time, small granular bodies, appearing in the equator of the spindle fuse to form a continuous membrane called **cell-plate** which extending entirely across the cell, divides it into two daughter cells, each with a newly formed nucleus in it.

(ii) **Meiosis or reducing division.**—This is a more complicated process than mitosis. In mitosis, the number of chromosomes always remains the same because each chromosome splits longitudinally and their halves separate. But an interesting modification occurs in meiosis by which **spores** are formed in plants. The chromosomes in this division do not split individually, but half their number becomes separated from the other half, hence the number of chromosomes present in the spores is half that present in the **sporophyte** or the plant-structure from which the spores arise. The spores of a fern on germination give rise to a small structure called **prothallus** on which the sexual cells are produced. The spores, as well as, all the cells, which the spores give rise to leading to the formation of sexual cells, contain the reduced number of chromosomes. At the time of the union of the sexual cells, the reduced number of

chromosomes will be doubled,thus making the number as was in the sporophyte.

Where the cells are formed.—To continue the life of a plant, protoplasm always produces new cells as one of its important functions. So, wherever there is active growth going on in the plants, as in the growing points of stems and roots or where there is the formation of reproductive organs, as endosperm, spores, pollen grains, etc., there must be the development of new cells out of the pre-existing old cells. Thus, both in the vegetative and reproductive organs, the old mother-cell gives rise to new daughter cells. New cells may arise by division or by the union of two into a single cell.

Cell-formation.—The following are the ways in which new cells are formed in the plant kingdom.

(1) **Ordinary cell-division.**—This usually occurs in the vegetative parts of plants. The division is preceded by the mitotic division of the nucleus. When a cell reaches a certain size, the nucleus at first divides karyokinetically into two, and two cells, each with a nucleus, result. These two daughter cells repeat the same process and a number of cells is thereby formed.

(2) **Free cell-formation.**—In this process, the nucleus of the cell divides repeatedly by karyokinesis and produces a a large number of parts, all lying free in the protoplasm. When the division is complete, the protoplasm arranges itself round each of the divided nuclei. Thus numerous naked cells are at first formed within the mother cell. Each of them now secretes a cell-wall round it. The new cells thus formed are usually liberated by rupture of the wall of

the mother cell, except in the formation of **endosperm.** When **pollen grains** are formed, nucleus at first divides into two, each of which divides again to form four. Protoplasm now divides itself into four parts and each part condenses round a divided nucleus. After the secretion of the cell-wall round the condensed protoplasm, four new cells are formed in their mother cell. These are the four pollen grains in each mother cell.

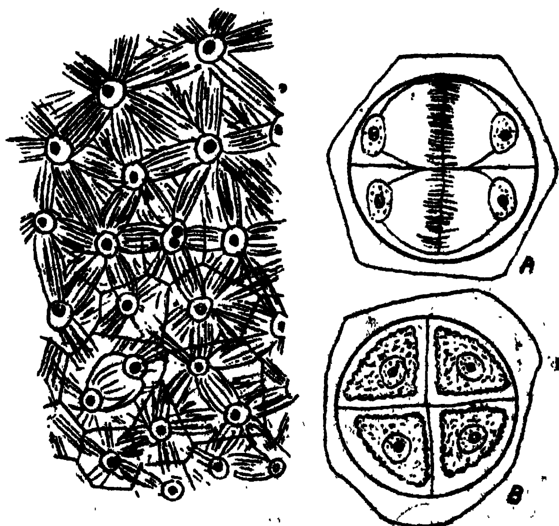


Fig. 133.

Formation of endosperm and pollen grains. A, B—Two successive stages of the formation of pollen grains.

When compared to the ordinary cell-division, the cell-walls, formed in this process of free cell-formation, are all new and do not belong to the mother cell.

When the free nuclear division is not followed by the formation of cell-walls, the cells become **multinucleate** as found in some thallophytes, where the division of nucleus is direct and not mitotic. Occasionally, peculiar multinucleate cells arise in which the nucleus undergoes repeated karyokinetic division without the formation of transverse septa between the resulting nuclei. These cells are called **coenocytes,** as found in the Fungi and laticiferous tubes of higher plants.

(3) **Rejuvenescence.**—In some plants, when the sexual or asexual cells are to be formed, the protoplasm of the mother cell recedes from the wall and contracts in the middle. The cell-wall now bursts to liberate the new protoplasmic mass which forms a new cell to serve usually the function of reproduction quite different from the function of the mother cell. In higher plants, young cells may be formed from old ones by rejuvenescence.

(4) **Fertilisation.**—When two differentiated sexual cells, one male and the other female, fuse together in such a way that the protoplasm of the male cell unites with that of the female and the nucleus of the one with that of the other, the process of fusion is called fertilisation. The result of the fusion of these two naked cells is the formation of a new cell, called **oospore.**

(5) **Conjugation.**—This is the process of fusion of two sexual cells when they can not be differentiated into male and female. The result of fusion is known as **zygospore.** This process usually occurs in the lower Cryptogams.

(6) **Fission.**—This method, common in the lowest organisms, as bacteria, consists in the constriction of the protoplasm and in the division of the nucleus without the complicated changes as are characteristic in the higher plants. The cell is divided into two equal parts.

(7) **Budding.**—This method consists in the protrusion of the cell-wall which is then separated from the parent cell by fission. This occurs in yeast plants (Thallophyte).

Summary of Chapter IV

The nuclear division is direct or indirect. Direct division is not followed by cell-division. The nucleus may divide itself by constriction. Indirect division or karyokinesis is of two kinds—mitosis and meiosis.

Mitosis occurs in four stages—prophase, metaphase, anaphase and telophase. In this process, the chromosomes are longitudinally split up into halves which move to the opposite poles.

Meiosis or reducing division is a more complicated process. Here, the chromosomes do not split individually but half their number becomes separated from the other half.

Cell-formation takes place both in the vegetative as well as in the reproductive parts. In the vegetative parts, new cells are formed by ordinary cell-division. In the reproductive parts, the cell-formation may take place in the following ways : —(1) free-cell formation, (2) rejuvenescence, (3) fertilisation, (4) conjugation. Budding or fission occurs in the lowest plants.

Exercise IV

1. Describe the various modes of cell-formation. —C.U. 1933.
2. How would you distinguish between ordinary cell-division and free cell-formation ?

CHAPTER V

TISSUE

A tissue is a collection of cells which take their origin from a single cell and grow in the same way to assume similar forms, all adapted to the same function. The constituent cells or vessels, as the case may be, composing a tissue are called **tissue-elements**.

Thus, if a transverse section of any organ of a higher plant be examined under the microscope, it is found to consist of different kinds of cells which are not distributed uniformly through the substance of the organ, but are collected in different ways.

Kinds of tissue

There are two chief types of tissue—**meristematic** and **permanent.**

Meristematic tissue or **Meristem** is usually found at the growing points of stems and roots. It consists of cells which go on dividing continuously to produce new cells. The small actively dividing cells have thin walls of cellulose. Protoplasm fills the cavity of each cell and contains a large nucleus. There is no vacuole and the plastids have not yet been formed. It is the meristem which gives rise to permanent tissues after numerous divisions and various processes of differentiation. The cells of permanent tissues assume

permanent or fixed forms adapted to definite function. Thus, the cells of meristem retain the power of growth, while those of a permanent tissue have lost that power.

Meristem may be **primary** or **secondary**)

Primary meristem—At the growing points, the meristem consists of a single actively dividing cell or a group of similar cells. This is really the mother of all other tissues of any organ. Just beneath this, the cells not only divide actively but become differentiated in three layers. All permanent tissues of stems and roots owe their origin from those three layers of meristem.) These are fully shown in the sections of the growing points of stems and roots.

As we examine the growing point further down, we recognise certain strands of cells, known as **procambial strands**. These are also meristematic cells which, by producing new cells externally and internally, give rise to vascular bundles consisting of xylem and phloem and persist as **cambium** between them in the dicot plants. In the monocot plants, these meristematic strands are scattered and become *completely* differentiated into xylem and phloem so that, *no portion persists as a meristematic layer* or cambium in the vascular bundles.

(**Secondary meristem** consists of living cells developed between the cells of the permanent tissue) They become meristematic in character, and, in consequence, divide continuously to produce new cells. During the secondary growth in thickness of dicot stems and roots, secondary cambium and cork-cambium are formed to divide actively.

B. (**Permanent Tissue.**—As growth goes on, the different layers of the cells of the primary meristem undergo

various modifications till they come to attain stable forms fit for individual functions. They are now the cells of permanent tissue. The cells are no longer small ; the large vacuoles press the protoplasm of the cells against the walls ; and the nucleus is smaller.

Permanent tissues are classified into four kinds according to the different forms and functions. They are—I **Cellular**, II **Vascular**, III **Laticiferous** and IV **Glandular**.

I. **Cellular tissue** consists entirely of cells. They may be (i) **parenchyma**, (ii) **prosenchyma**, (iii) **sclerenchyma** and (iv) **tracheides**.

(i) **Parenchyma** may be thin-walled and thick-walled.

Thin-walled parenchyma is further classified into (1) **chlorenchyma**, (2) **storage parenchyma** and (3) **aerenchyma**.

(1) **Chlorenchyma** consists of cells which contain chloroplasts. The cells are thus green and fit for carbon assimilation. They are always living and prepare assimilatory starch of the plant. They are found in the mesophyll of leaves, cells of Algae, cortex of stems, etc. (Fig. 124).

(2) **Storage parenchyma** consists of cells which may contain leucoplasts and thus prepare starch out of the sugar solution when transferred in these cells. Reserve starch, proteids, oils, etc., are present in these cells. They are found in the interior of stems, roots, seeds, etc. (See Fig. 125).

(3) **Aerenchyma** consists of many living cells. The air-cavities are within these cells or outside them as large inter-cellular spaces. They are found in aquatic plants which are made light owing to the storage of air in

the tissue. Typical aerenchymatous cells are found in the floating roots of *keshardam*, *hincke*, etc. (See page 35)

Thick-walled parenchyma consists of living cells with their walls thickened.

(1) **Collenchyma** is a type of thick-walled parenchyma. The cells of this tissue acquire thickenings by cellulose deposits, specially at the corners. They are found just below the epidermis of many stems and leaf-stalks. They usually serve the mechanical function but when they are green and with chloroplasts, carbon assimilation is another function.

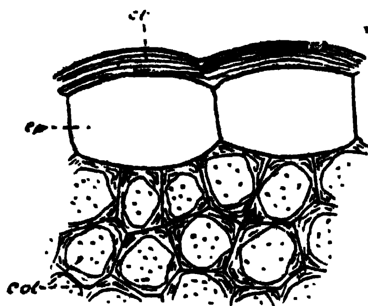


Fig. 134.
Collenchyma. ep--Epidermis ct – Cuticle ; col - Ccollenchyma with chloroplasts.

(ii) **Prosenchyma** may be thick-walled or thin-walled. There is thus no sharp line of demarcation between parenchyma and prosenchyma. The cells of parenchyma are usually living, more or less roundish in form and serve functions in connection with assimilation and storage. Usually prosenchymatous cells, on the other hand, soon lose their living contents and become dead. These cells are mostly thick-walled and elongated. They are pointed at the two ends and slightly swollen in the middle. They are arranged in an interlocking manner, *i. e.* the pointed end of one cell is fitted closely between the middle portions of two neighbouring cells. When thick-walled, they are the **fibrous cells** in the bundle.

(iii) (**Sclerenchyma** is made of cells which are dead and elongated. Their walls are lignified and highly thickened.) The thickening is sometimes so great that the cell-cavities can not be discerned. They are largely distributed in stems, roots and some leaves. Their function is purely mechanical, so they give strength to the plant body. They are so compactly arranged that they leave no intercellular spaces between them. Typical sclerenchymatous cells are prosenchymatous and are known as **sclerenchymatous fibres**. They occur in bands in the hard bast of many plants. Sometimes, parenchymatous sclerenchyma is also met with and consists of **sclerotic cells**.

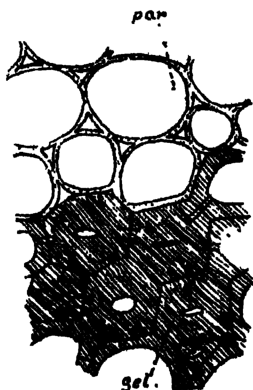


Fig. 135.
Par—Parenchyma.
Scl—Sclerenchyma.

(iv) **Tracheides** are dead and much elongated prosenchymatous cells found in the wood of most plants, specially Gymnosperms and Pteridophytes. Their walls are lignified and have thickenings of various patterns on them, viz. **spiral, annular, reticulate, pitted, scalariform,** all adapted for mechanical function. They are mainly used for the conduction of watery solution from the roots to the leaves and also for the storage of water and slow conduction thereof.

II. (**Vascular Tissue** consists of **vessels**.) (A vessel is a long channel-like body composed of a row of elongated

cells which are attached end to end and which have their partition-walls between them absorbed wholly or partially. The continuous passage, thus formed within the plant, facilitates the easy transport of food solution. There are two forms of vascular tissue :—(1) the first form consists of **tracheae** or **wood-vessels** and (2) the second form consists of **sieve tubes.**

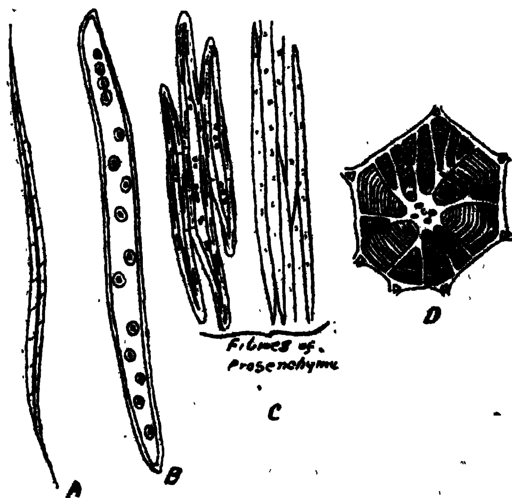


Fig. 136.
Hard elements A—Sclerenchymatous cell. B—Tracheide. C—Fibres. D—Sclerenchymatous cell in the transverse section.

(1) **Wood-vessels** along with tracheides are the chief elements of the wood or xylem of the vascular bundles. With tracheides they form **tracheal tissue**. The wood-vessels agree very closely with the tracheides. In the same way, they are thickened in various ways. So **spiral, annular, pitted, reticulate** and **scalariform** vessels are

found in wood. They discharge the same functions as in the case of tracheides. The only difference lies in the fact that a tracheide develops from a single cell but the wood-vessel is derived from a row of cells by fusion.

(2) **Sieve-tubes** are the chief elements of the phloem of a vascular bundle. Each vessel is a long tube consisting of elongated cells which have their partition-walls not completely absorbed but perforated in the form of a sieve. The tubes are so named owing to the formation of such partition-walls called **sieve-plates**. Unlike wood

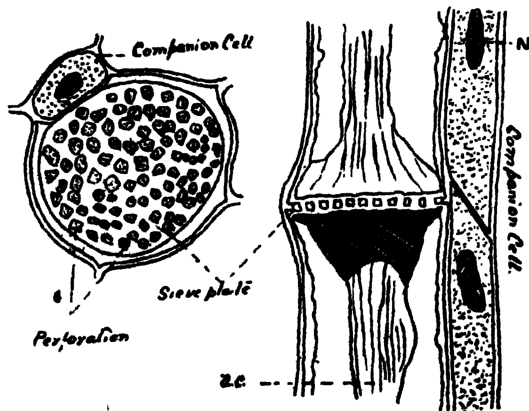


Fig. 137.
Sieve tube vessels.
ac—Albuminous contents. N—Nucleus.

vessels, their walls are not lignified but thin and made of cellulose. The tubes are not dead but contain a thin layer of protoplasm without any nucleus. Through the pores of the perforated walls nitrogenous matters pass easily. But in the winter the pores are closed by the deposition of a

thick layer of cellulose matter called **callus**. The callus, however, dissolves again in spring when the growth of the plant is vigorous.

Closely associated with the sieve-tubes are long, thin-walled **companion cells** which contain abundant protoplasm with nucleus. They are cut off from the sieve-tube mother-cell during development. They are found only in Angiosperms.

(III) **Laticiferous tissue.**---This consists of long thin-walled branched tubes full of a peculiar substance called **latex**. Regarding colouration, latex may be yellow, milky or watery. Numerous waste products, as resin, gum, tannin, guttaparcha, etc., are present in the latex. Sometimes, it contains dumb-bell-shaped starch, albuminoids and other nutritive substances.

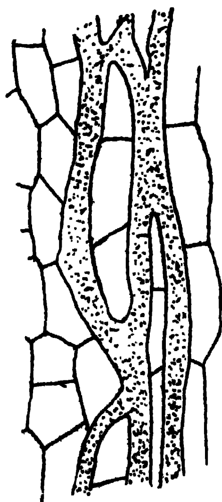


Fig. 138.
Laticiferous tubes.

The tissue consists of both **vessels** and **cells**. The **laticiferous vessels** are not formed ordinarily by the fusion of partition-walls, as seen in the vascular tissue, but by the absorption of the lateral walls only at those places where they come in contact with other cells so as to produce a much-branched tubular body. The vessels ramify and form a close network. These vessels are found in *sealkanta*, *rerhi*, *kola*, *bharenda*, etc.

Laticiferous cells are in the forms of coenocytes. A coenocyte is a much-branched multi-nucleated body having no transverse septa in it. It differs from ordinary multi-nucleate cell in this, that in coenocyte the nuclear division begins from the embryonic stage while in ordinary cell it occurs in old stage. These laticiferous coenocytes are found in *bot*, *karabi*, *akanda*, *kantal*, etc.

(IV) **Glandular tissue.**—This consists of a single cell or a group of cells which contains secreted and excreted matters, as sugar, water, gum, resin, tannin, ethereal oils. etc.

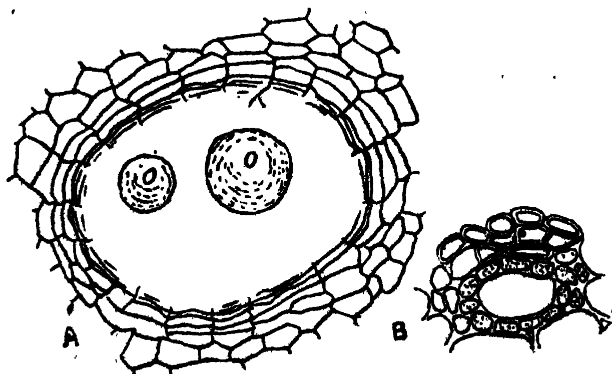


Fig. 139.

Glands. A—Oil gland of orange rind. B—Resin duct.

Glands are (a) **unicellular**, (b) **multicellular** or (c) **hairy.**

(a) **Unicellular glands.**—Isolated single cells differing from other cells of a tissue in their contents are known as **idioblasts** when they serve as glands, as found in many water plants, as *padma*, *kachu*, *shaluk*, etc., in which the cells contain raphides. Cells containing mucilage are found in the leaves of *orchid*, *kachu*, *gritakumari*, *puin*, etc.

(b) **Multicellular glands** arise from a group of cells. They may be **solid** or **hollow**. The nectaries of flowers secrete sugary fluids for the attraction of insects. The leaves of insectivorous plants secrete digestive fluid for the digestion of the entrapped insect. Glands in *ghash*, active in secreting or excreting water, are called **hydathodes.** Hollow multicellular glands appear in the form of long cavities or ducts filled with the secreted substance. The oil ducts on the lemon rind arise lysigenously. But the resin ducts of *pine*, *surjamukhi* and the gum ducts of *dhania*, *mouri*, etc. arise schizogenously. A duct, as in the case of *nebu*, is usually surrounded by a layer of secretory cells of parenchyma called **epithelium**. These cells are highly active in secreting oil which is poured into the duct to fill up.

(c) **Hairy glands**, arising from epidermis, may be unicellular or multicellular, as in *bichuti*. All the cells of the hair or only the end-cells are secreting.

Exercise V

1. What is a tissue? What are the chief types of tissues? Where do they occur? Give sketches.—C. U. 1932, 1930, 1927, 1924, 1922, 1912.

2. What are vessels and tracheides? Describe their forms.—C. U. 1932.

3 Describe sieve tubes, bordered pits and any gland with sketches.—C. U. 1930, 1924, 1917, 1914.

Tabular Summary of different tissues

- Tissue
  - Meristematic
    - Primary
    - Secondary
  - Permanent
    - Cellular
      - Parenchyma
        - Thin-walled
          - (1) Chlorenchyma
          - (3) Aerenchyma
          - (2) Storage parenchyma
        - Thick-walled
          - (1) Collenchyma
      - Prosenchyma
        - Thin-walled
        - Thick-walled
      - Tracheides
      - Sclerenchyma
        - Fibrous
        - Sclerotic
    - Vascular
      - Wood vessels
        - Spiral
        - Annular
        - Reticulate
        - Pitted
        - Scalariform
      - Sieve-tubes
    - Laticiferous
      - Vessels
      - Coenocytes
    - Glandular
      - Unicellular
      - Multicellular

CHAPTER VI

TISSUE-SYSTEM

Definition.—In all roots, stems and leaves, different forms of permanent tissues are grouped together to form higher histological units called tissue-systems.

Kinds of tissue-systems :—The three principal systems are :—(A) **Epidermal or tegumentary system**, (B) **Vascular system**, (C) **Fundamental or ground tissue-system**.

(A) Epidermal system

This system includes all the superficial tissues of the plant-body which protect the inner tissues from excessive evaporation and external injuries. In all the leaves and young stems of higher plants, it generally consists of one layer of cells known as the **epidermis** which in old stems is replaced by **cork** or **bark**.

As a rule, the epidermis is one cell in thickness. There are exceptions where the epidermis consists of several layers of cells, as in the aerial roots of orchids (velamen), the upper surface of the leaves of *bot* and allied plants, etc. A many-layered epidermis usually serves to store up water. Generally, epidermis consists of three types of cells. (1) **Ordinary cells**, (2) **cells of stomata**, and (3) **Epidermal outgrowths.**

(1) **Ordinary cells** of epidermis are brick-shaped or hexagonal in form. In some cases, they have wavy margins. They are compactly arranged, so that the inter-cellular spaces are absent in them. They contain protoplasm and colourless cell-sap. Except in ferns and other shade-loving plants,as well as,in some water plants, the chloroplasts are as a rule absent. Their outer wall is cuticularised and is much thicker than the inner one. A layer of cutinised



Fig. 140.
Stomata on a leaf. The upper three cells a, b, c, show the gradual formation of a stoma.

substance called **cuticle** covers the outer wall of the epidermal cells except the stomata. The cuticle is impervious to water vapour and thus economises the water supply of plants growing in dry climate by checking undue evaporation. Sometimes, cuticle is covered with a thin layer of wax called

bloom, as found on *chalkumra* fruits, *akanda* leaves, etc. This prevents the surface from being wetted by water.

(2) **Stomata** are found on the aerial parts of plants. They are numerous on leaves specially on the under surface. In floating leaves they are found only on the upper surface. Each stoma is a minute pore bounded by two semi-lunar cells called **guard-cells**. The pore opens into a big intercellular air-space in the underlying tissue. Unlike epidermal cells, the guard-cells contain chlorophyll. A stoma takes its origin from a young epidermal cell which divides itself equally into two parts by a septum. By the splitting of the septum the pore is formed. Sometimes, the surrounding epidermal cells divide to form **subsidiary cells** of a stoma.

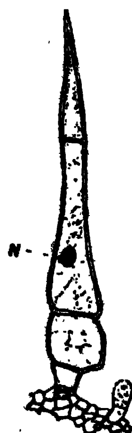


Fig. 141.
Hair on *kumra* fruit.

The walls of guard-cells are not uniformly thickened. Those which are away from the pore are thinner than those nearest the pore. The pore opens in the light and closes in darkness. The stomata serve for the interchange of gases and water vapour through the pores between the internal tissues and external atmosphere. This takes place so long the stomata are open.

(3) **Epidermal outgrowths** include hairs, prickles, bristles, tentacles, etc. They all arise from epidermal cells. Though they may be of varied forms, they are usually long and filament-like. They may consist of a single or several cells. **Prickles** are distinguished from **hairs** in taking their origin not only from the epidermal cells but also from some

of the cortical cells. **Bristles** are stiff hairs as found on the stems of *bichuti*, *kumra*, etc.

Hairs discharge many functions, as in the following :—

(a) The unicellular root-hairs are always meant for absorbing food solution from the soil.

(b) The hairs on the aerial parts protect plants from the attacks of insects, snails, etc.

(c) Besides protection, the glandular hairs (**tentacles**), found in insectivorous plants, serve to entrap insects and help the digestion by secreting a fluid.

(d) Hairs, secreting or excreting water, called **hydathodes**, consist of epidermal or sub-epidermal cells.

(e) The hairy stigma not only fixes the pollen grains on it but secretes a sugary fluid necessary for the germination of the grains.

(f) Hairs, being cuticularised and impermeable to water, serve to protect the young parts of plants from an excessive loss of water.

(g) A close covering of hairs prevents the growing organs from the injurious effects of strong light.

(h) When thickly set, hairs can retain heat during the night thereby keeping the plant-body warm.

(i) The crowded hairs also prevent the surface from being wetted by rain.

(j) The tufts of hairs developed on many seeds, such as *akanda*, *kapas*, etc., help their dispersal. For the same purpose, the persistent hairy calyx (pappus) is useful.

(B) Vascular system

This system consists of vascular bundles which are composed of **xylem** or **wood** and **phloem** or **bast**, separately

as in roots, or conjointly as in stems and leaves. The bundles are present in all organs of Pteridophytes and Phanerogams. They are continuous in stems, roots and leaves. They form a conducting system of the plant, i. e., they conduct raw food solution from the roots to the leaves through the stems, and elaborated food from the leaves to the different parts of the plant. As the bundles consist mainly of hard elements, they give mechanical strength forming the frame-work upon which the softer parts of the plant are fixed. They resist decay longer than other parts of the plant.

Besides xylem and phloem, bundles may also possess a **cambium**. Such bundles are called **open** as they are open to growth due to the activity of the intervening cambium. They are found in Dicot plants and Gymnosperms. When bundles consist of xylem and phloem only, as in Monocots, they are called **closed** ; growth in thickness does not take place in them.

According to the different positions of xylem and phloem, bundles, are said to be—(a) **Collateral**, (b) **Bicollateral**. (c) **Radial** or (d) **Concentric**.

(a) **Collateral**—Xylem and phloem are in contact and lie one above the other. Xylem is placed below and phloem on the outer side of it. This is common in all stems of Dicots (with a few exceptions), Monocots and Gymnosperms. In leaves, xylem lies towards the upper surface and phloem towards the lower.

(b) **Bicollateral.**—Xylem forms one mass in the middle and phloem is situated on both sides of it. The three lie in one radial line in the bundle. This is found in the stems of *kumra*, *shasha*, and other plants of the family.

(c) **Radial.**—This is the characteristic arrangement of all root bundles. Xylem and phloem elements are equal in number and form separate bundles. They are placed alternately on different radii, as seen in the transverse section.

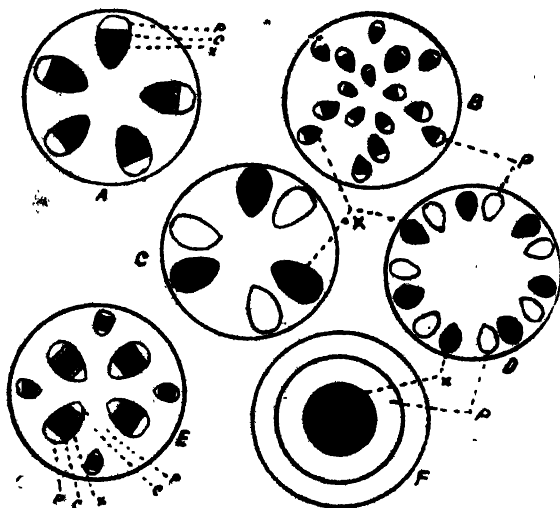


Fig. 142.

Arrangement of xylem and phloem. A—Dicot stem. B—Monocot stem. C—Dicot root. D—Monocot root. E—*Kumra* stem. F—Fern stem. x—Xylem. p—Phloem. c—Cambium.

(d) **Concentric.**—Xylem in the centre is surrounded by phloem, as in fern stems, or phloem in the centre is surrounded by xylem, as in a few Monocot stems.

Bundles in Monocot stems and leaves are usually surrounded by a few layers of sclerenchyma or parenchyma. These form the **bundle sheath**.

Xylem is the woody portion of the bundle. In stems, it develops centrifugally, that is, from the centre towards the outside. The first-formed xylem, known as **proto-xylem**, consists of **spiral and annular vessels**. In an advanced stage, the xylem is called the **meta-xylem** which consists of all types of **wood-vessels** and **tracheides**. Along with these, there are also parenchymatous cells forming **wood parenchyma** and long and narrow fibrous cells forming **wood fibres**. The wood parenchyma and wood fibres serve to store up starch grains for future use.

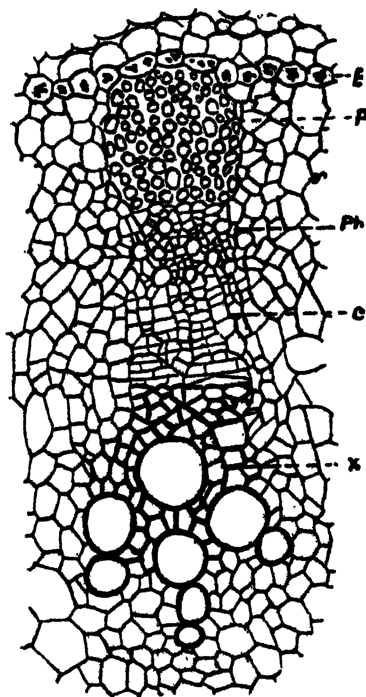


Fig. 148.
A bundle with xylem, phloem and cambium. Ph—Phloem ; x—Xylem ; c – Cambium ; p—Pericycle ; e—Endodermis.

Phloem is another important portion of the bundle. It conducts the elaborated food from the place of assimilation to the different parts of the plant, where necessary. It develops both in stems and roots centripetally, that is, from outside towards the centre. The first-formed phloem, called **proto-phloem**, consists of narrow **sieve-tubes** with which long thin

walled **companion cells** are found. **Meta-phloem,** i. e. the older part of phloem, consists of sieve-tubes, companion cells and also a few cells of parenchyma called **phloem parenchyma** and long, narrow, fibrous cells called **bast fibres.**

(C) Ground tissue-system.

This system includes all the tissues which do not belong to the two systems described above. They serve functions of nutrition and form storehouses for reserve food.

The tissue, lying outside the region in which the vascular bundles are embedded, and which is known as **stele**, are called **extra-stelar,** whereas the tissues which lie within the stele and connect the vascular bundles are called **intra-stelar** or **conjunctive**. Extra-stelar tissue includes **cortex** with **endodermis,** and **pericycle** ; the intra-stelar tissue includes **medullary rays** and **medulla** or **pith**. These tissues will be fully explained later.

Hard bast, common in use in histology, is a misnomer. It does not belong to the bast or phloem but to the ground tissue. It usually consists of fibrous sclerenchyma, a strengthening tissue. It represents the **pericycle** when it becomes lignified at the head of the bundles, as seen in the section of a sunflower stem.

Strengthening or mechanical tissues

There are various forms of these tissues which are arranged differently in the different organs of the plant. Their chief function is to give strength and rigidity to the parts where they occur.

They are as follows :—

(1) **Collenchyma** occurring in the hypodermis of stems. (2) **Sclerenchyma**, the chief tissue, distributed in the periphery of stems or roots, in the pericycle as a continuous ring or in patches, in the Monocots as bundle-sheath or in patches. (3) The **fibres** of xylem or phloem. (4) The ring of **Cork** strengthening the inner tissues. (5) The net-work of **veins** lending supports to the leaves. (6) **Closely arranged bundles** in the roots, specially of the Monocots. (7) **Parenchyma** giving rigidity to the water plants, when turgid.

Mode of distribution of the strengthening tissue.— The strengthening tissues are arranged in such a way as to meet the strains to which the organs are subject. When an organ is placed under the influence of bending strains from wind or storm, the strain falls on its two sides. The tissues on the convex side are highly stretched while those on the concave side are compressed. There is no strain in the middle. Thus, the strengthening tissues are accordingly arranged more near the periphery where the strain is maximum. The water plants withstand their pulling strains, for their weight is upheld by the water. The strengthening tissues, in this case, are usually placed in the centre.

Summary of Chapter VI

1. Tissue-system consists of several permanent tissues grouped together to serve a common function.

2. The three tissue-systems are (1) epidermal, (2) vascular, and (3) fundmental.

3. **Epidermal system** consists of epidermis, cork or bark. Epidermis consists of rectangular cells, stomata and outgrowths. The rectangular cells are closely arranged and have the outer walls cuticularised. Each stoma is a pore bounded by two green guard cells The whole system is protective.

4. **Vascular system** consists of **xylem** and **phloem** separately or conjointly. The arrangement of xylem and phloem occurs **collaterally, bi-collaterally, radially** or **concentrically**. The bundles with xylem, phloem and cambium are open as opposed to closed where the cambium is absent. Xylem consists of vessels, tracheides, parenchyma and fibres. Phloem consists of sieve-tubes, companion cells, parenchyma and fibres. Xylem conducts raw food and phloem, elaborated food. The development of xylem is centrifugal in stems but centripetal in roots. Phloem always develops centripetally both in stems and roots.

5. **Fundamental system** consists of cortex, pericycle, medullary rays and pith.

6 Strengthening tissue.—They are distributed in the different regions of the plant according to the strain to which the plant is usually subject.

Exercise VI

1. What are stomata? Describe their structure and functions. —C. U. 1929, 1917, 1916.

2. Describe the tissue-elements that you observe in the fibro-vascular bundles of a dicot. What is the importance of vascular tissues in plants?—C. U. 1930, 1915, 1913.

3. Describe the distribution of strengthening tissues in land plants or in water plants. How does the arrangement meet the requirements of the plants in each case? C. U. 1923.

CHAPTER VII

DISTRIBUTION OF MERISTEMATIC AND PRIMARY TISSUES

(A) Growing point of a shoot

We have seen before that the growing points are occupied by an actively dividing tissue. If a longitudinal section of a growing point be examined, it is found, that

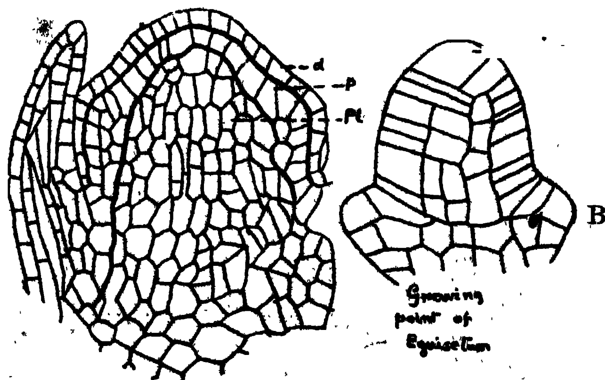


Fig. 144.
Growing points of shoot. A—Dicot stem. B—Equisetum stem. d—Dermatogen. P—Periblem. Pl—Plerome. i. c.—Apical cell.

just at the extreme tip there is a group of cells which are all similar and which by their continual division give rise

to other meristematic cells below. In some Pteridophytes there is at the head a single triangular cell from which all other cells take their origin by its divisions on the sides.

Just below the cells at the head, the meristem is differentiated into three distinct layers of cells : they are from outside within :—

(1) **Dermatogen** or the outermost layer which covers externally all other layers of cells. The cells of this layer divide up by walls formed at right angles to the surface. This gives rise to epidermis of the young shoot after divisions.

(2) **Periblem** or the second layer lying just below the dermatogen. It is one layer of cells thick at the apex, but lower down, owing to the irregular divisions of cells, it becomes many layered. It forms, after divisions, the three differentiated parts of cortex, namely, hypodermis, cortex proper and endodermis.

(3) **Plerome** or the central part which consists of a few layers of cells. It gives rise to all the tissues lying within the endodermis namely, pericycle, vascular bundles, medullary rays and pith. The vascular bundles owe their origin from several longitudinally divided cells of plerome which become longer and narrower than the rest. These are called **procambial strands**. A few cells of these strands lying towards the centre form **proto-xylem** while the outer cells of the strands produce **proto-phloem**. The cells, in the middle, form a layer of meristem, called **fascicular cambium** which goes on dividing and adding cells to xylem and phloem.

(B) Growing point of a root

The growing point of a root agrees in many respects with that of the shoot, but it differs from the latter in the behaviour of the dermatogen. The three differentiated layers of meristem grow and are placed in the same way as in shoot. But the dermatogen at the head undergoes repeated divisions both perpendicularly and tangentially and produces a mass of cells which form the many-layered **root-cap** at the apex of the root. A little behind this, the root-cap merges into a single layer of dermatogen which forms after divisions the piliferous layer bearing mainly unicellular root-hairs. The layer of dermatogen in root which thus forms both the root-cap and the piliferous layer is called **calyptrogen**. The root-cap is constantly being renewed from within as it is gradually worn away, when it passes through the soil and comes in contact with the sharp soil particles. As in shoot, plerome produces also procambial strands, but these strands, instead of developing proto-xylem towards the centre and proto-phloem on the outer side give rise to both xylem and phloem on the *outer side only*.

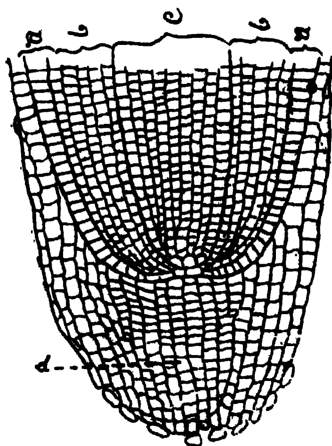


Fig. 145.
Growing point of root.
a—Dermatogen. b—Periblem.
c—Plerome. d—Root-cap.

Growing points of dicot & monocot roots compared :

(1) Dermatogen, in dicot roots undergoing divisions, forms the root-cap but in monocot roots, dermatogen and periblem unite at the apex to form a single layer, beyond which lies the calyptrogen to form the root-cap.

(2) In dicot roots, root-cap merges into a single layer of dermatogen just behind the tip, so one can not be distinguished from the other. But in monocot roots it is easy to mark how far the root-cap extends.

(3) Root-hairs in dicot roots arise from the dermatogen while in monocot roots, they arise from the periblem.

PRIMARY TISSUES

We are now in a position to examine the primary tissues distributed in the internal structures of young stems, roots and leaves.

STEMS

A. The structure of a youg dicot stem.

In the transverse section, the following are the tissues arranged from outside within ;—

(1) **Epidermis** is the outermost tissue,the cells of which are one-layered, closely arranged and rectangular in form. The outer walls are cuticularised. Chloroplasts are absent in the cells. At places, the cells are replaced by stomata and hairs. Each stoma consists of a pair of guard-cells. The hairs are usually multicellular and protective.

(2) Next to epidermis, there are several layers of **cortex** divided into three parts, viz, hypodermis, cortex proper and endodermis.

(a) **Hypodermis** consists of collenchyma or sclerenchyma. In some stems, both the tissues are present. (b) **Cortex proper** consists of several layers of parenchyma of which the outer ones are more green than the inner, where assimilatory starch is abundant. (c) **Endodermis** or the last layer of cortex consists of a single layer of rectangular

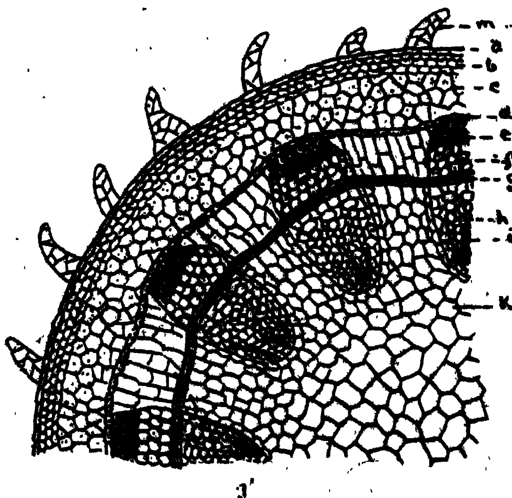


Fig. 146.

Cross section of a sunflower stem. a—Epidermis. b—Hypodermis. c—Cortex proper. d - Endodermis. e—Pericycle. f—Phloem. g—Cambium. h Xylem. i - Medullary rays. k - Pith. m—Hairs.

cells, the radial walls of which are suberised. The cells contain many tarch grains and hence they form starch-sheath. In some stems, the endodermis cannot be distinguished.

(3) Next to endodermis, lies **pericycle** of one or several layers of cells. In some stems, this may be absent or not so well-developed. This may be thin-walled or lignified. When the cells of pericycle become sclerenchymatous at the head of the bundles, they form **hard bast**. (See page 232).

(4) Next to pericycle, the **vascular bundles** are arranged in a ring. In a very few cases, the rings are more than one. In *kumro* and allied stems, *krishnakali*, *begoon*, *padma*, *pan*, etc. the ring of bundles is never single. Each

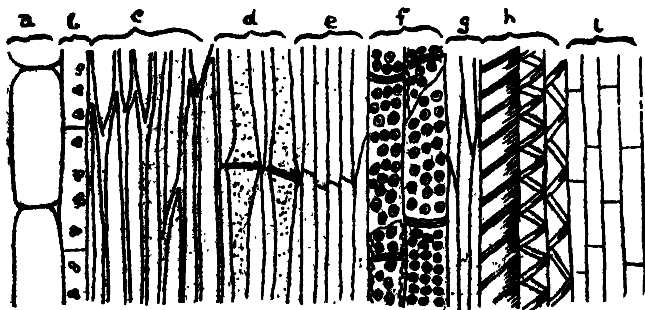


Fig. 147.
Longitudinal section of sunflower stem. a – Cells of cortex proper. b – Endodermis. c – Pericycle. d – Phloem. e – Cambium. f – Pitted vessels of xylem. g – Fibres. h – Other vessels of xylem. i – Pith.

bundle consists of **xylem**, **cambium** and **phloem**. As xylem is internal and phloem is external in the bundle, the arrangement is **collateral**. Bundles are **open**, as cambium intervenes between xylem and phloem. For the elements of xylem and phloem (see page 231).

(5) **Medullary rays** consisting of elongated cells of parenchyma are radially situated between the bundles.

(6) **Pith** forming the core consists of big parenchymatous cells full of starch grains. Sometimes, pith is absent.

B. Structure of the monocot stem

The following tissues are found in the transverse section :—

(1) **Epidermis**, as in Dicot stem, consists of brick-shaped cells in one layer. The cells have cutinised outer walls.

(2) **Ground tissue** fills up the whole internal space excepting those occupied by the bundles. This is not

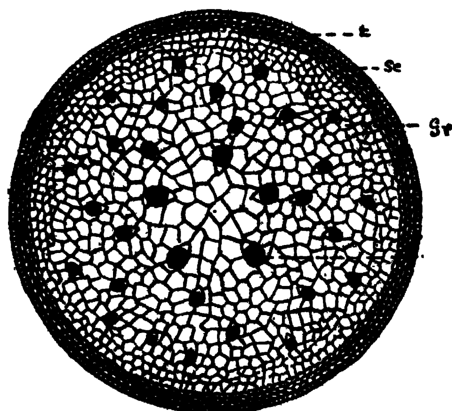


Fig. 148.

Cross section of a Monocot stem. E—Epidermis. sc—Sclerenchyma. Gr—Ground tissue. B—Bundle.

differentiated as in Dicot stems. Cortex proper, endodermis, pericycle, medullary rays and pith are not distinct. All the cells of the ground tissue, with the exception of those in the periphery, are parenchymatous. The hypodermis usually consists of a few layers of sclerenchyma which is closely associated with the several patches of sclerenchyma connecting the peripheral bundles. In lily and other allied stems, pericycle of a few layers is differentiated.

(3) **Bundles** are more numerous than those in Dicot stems. They seem to be scattered, but when closely examined, they are found to be arranged in several rings. Bundles are **closed**, as they possess only xylem and phloem arranged **collaterally.** Each bundle is surrounded by a sclerenchymatous **bundle-sheath.** The elements of xylem and phloem are mainly the same as in Dicot bundles. The big cavities in the centre of a bundle represent the big pitted vessels. There is no new addition of elements to the xylem and phloem owing to the absence of the intervening cambium. It is for this reason that growth in thickness in Monocot stems is impossible except in a few cases as *Dracaena*, *Yucca* and some palms.

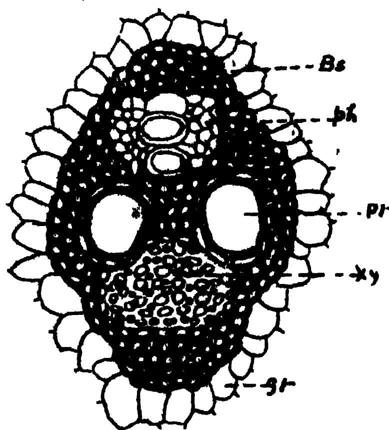


Fig. 149.
Monocot stem bundle. Bs—Bundle-sheath. Ph—Phloem. Pt—Pitted vessel. Xy—Xylem. Gt—Ground tissue.

C.—Structure of pine stem (Gymnosperm).

Generally, the stem agrees with that of a Dicot, from which it differs in the following points :—

(1) **Xylem** consists mostly of **tracheides** which may be spiral, annular and pitted. The **wood vessels** are absent. **Bordered pits** on the tracheides are very common and prominent.

(2) **Phloem** has **no companion cells**, which are replaced by **albuminous cells**. The **sieve-plates** are on the **lateral sides**.

(3) **Resin ducts** are present in the cortex as well as in the wood.

(4) **Medullary rays are very complex**. Those in the xylem consist of **starch-containing cells** and **tracheides**. Those in the phloem have **starch** in some and **albumen** in others.

In **Cycas**, another **Gymnosperm**, the ducts secrete mucilage and the xylem consists of only tracheides. The starch-containing pith occupies a large area.

D. **Structure of Fern** (a Pteridophyte) **stem**.

The stem is characterised by the following peculiarities :—

(1) **Epidermis** is the outermost layer in most of the stems. This single layer has the cell-walls wavy. The cells may contain chloroplasts.

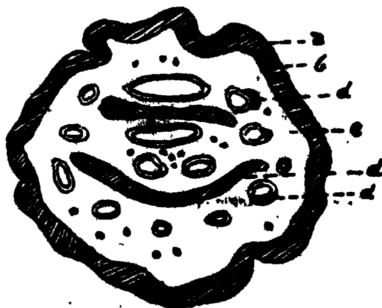


Fig. 150.
Fern stem section (diagrammatic).
a—Epidermis. b—Sclerenchyma.
c—Ground tissue. d—Stele.

(2) **Hypodermis**, next to epidermis, consists of a few layers of **sclerenchyma**.

(3) **Ground tissue**, next to hypodermis, consists of parenchyma which fills up the whole space excepting the steles.

(4) **The steles** are many in the stem which consequently becomes **polystelic** ; rarely it becomes monostelic.

(5) Each stele is surrounded by (a) single layer of **pericyle** and then by (b) one or two layers of **endodermis.**

(6) A stele consists of **parenchyma** in which **xylem** and **phloem** elements lie embedded. The xylem is in the middle of the stele and is surrounded by the phloem.

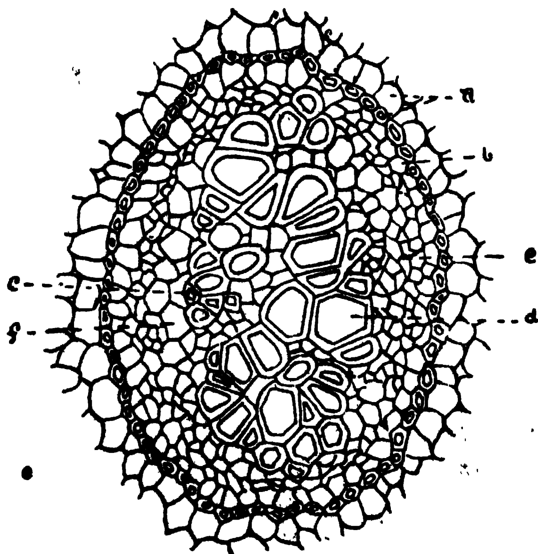


Fig. 151.

Transverse section of a Fern stele. a—Endodermis. b—Pericycle. c—Smaller elements of xylem. d—Bigger tracheides. e—Parenchyma. g—Phloem.

The arrangement, thus, is **concentric. There is no cambium.** Xylem consists mainly of **scalariform tracheides** besides others of **spiral and annular types, and parenchyma.** Proto-xylem consisting of small spiral tracheides is at the end of the xylem. Phloem consists of

mainly **sieve** tubes and **parenchyma**. As in the pine stem, **companion cells** here **are totally absent**, and the **sieve-plates are lateral** instead of being transverse.

E. **Structure of Selaginella stem** (another Pteridophyte)

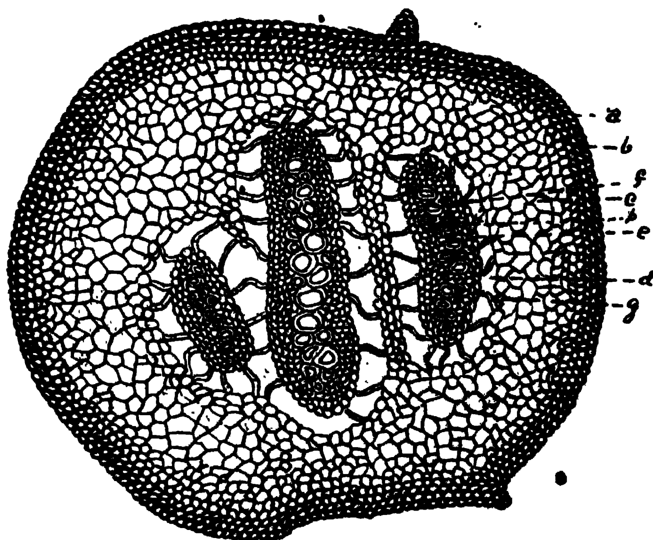


Fig. 152.

Selaginella stem. a- Epidermis. b - Sclerenchyma. c—Ground tissue. d—Air space. e - Pericyle. f—Xylem. p—Phloem. g—Endodermis.

Selaginella, being a Pteridophyte agrees in most respects with the structure of Fern stem. The following points should be noticed :—

(1) As in Fern stem, its stem is mostly **polystelic** and sometimes **monostelic.**

(2) Each **stele** is surrounded by an **air space** which is bridged over by long rows of cells connecting the stele with the parenchyma of the ground tissue or with the neighbouring stele. These connecting cells are thin-walled

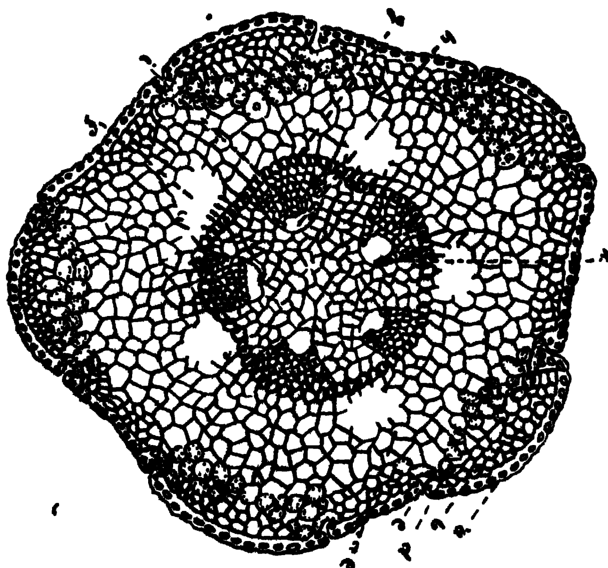


Fig. 153.

Equisetum stem. a—Epidermis. b—Sclerenchyma. c—Stomata d—Chlorophyll-containing cells. e—Cortex. f—Vallecular cavity. g—Endodermis. h—carinal cavity. i—Phloem. k—Xylem

and represent the **endodermis** of the stele. This differs Selaginella from Ferns and other Pteridophytes.

(3) The **xylem** is usually developed **centripetally**: proto-xylem groups are on the outside.

F. **Structure of Equisetum stem.** (Pteridophyte)

Though Equisetum is a Pteridophyte, the internal structure of the stem approaches most nearly to that of a Dicot. As in the Dicots, the separate bundles are arranged in a ring which is surrounded by a layer of pericycle and then by the one-layered endodermis. The stem is ribbed, that is, there are ridges and furrows. The stem is characterised by the development of intercellular spaces appearing in two rings. Those spaces in the outer ring called **vallecular cavities** are in the cortex and stand in front of the furrows, while those in the inner ring called **carinal cavities** are placed below the bundles and stand in front of the ridges. The vallecular cavities are full of air, while the carinal cavities contain water. The bundles are all closed. The two groups of xylem on the two sides of a bundle enclose one group of phloem in the middle.

ROOTS

A. **Structure of a young Dicot root.**

On cutting a transverse section of a young root, the following tissues are noticed from outside within :—

(1) **Piliferous layer or epiblema** is the outermost layer. Though it corresponds to the epidermis of the stem in position it does not agree with its structure and function. It bears many **unicellular root-hairs** in one layer which absorb food from the soil.

(2) Next to epiblema, is the **cortex** which is differentiated into two parts, namely, **cortex proper** and **endodermis** but when epiblema vanishes, **exodermis**, the third

differentiated part, forms the outermost protective layer. Sometimes, exodermis is present internal to epiblema. Cortex proper consists of several layers of parenchyma without

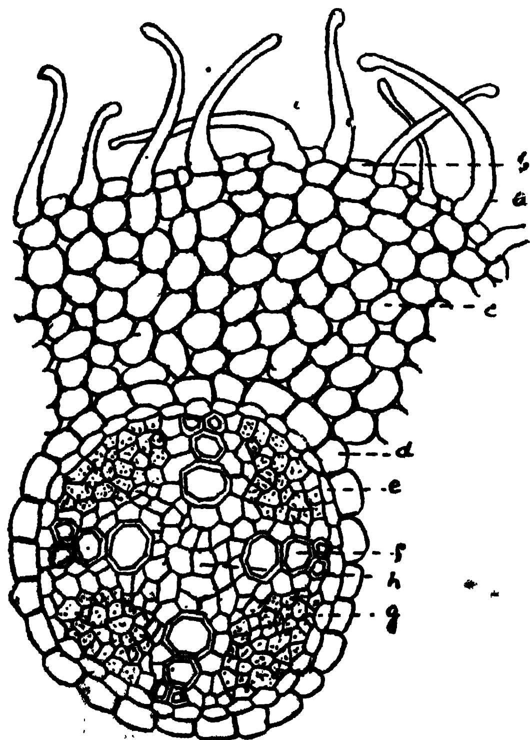


Fig. 154.

Cross section of a dicot root. a—Root hair. b—Epiblema. c—Cortex d—Endodermis. e—Pericycle. f—Xylem. g—Phloem. h—Pith.

chloroplasts. Endodermis is always present in the root as a single-layered distinct tissue. The suberised radial walls and the presence of abundant starch in the cells are the characteristics of endodermis.

(3) **Pericycle** lying just below endodermis is also one-layered and distinctly developed. The cells are all thin-walled. This is a very important layer in roots, as rootlets take their origin from this layer. So their growth is **endogenous**. Pericycle also takes part in the development of cambium formed during secondary growth.

(4) **Bundles—Xylem and phloem** form **separate bundles**. They are equal in number and are alternately arranged on the different radii. Hence their arrangement is **radial**. Cambium is absent in the young root but arises only in connection with secondary growth. Proto-xylem and proto-phloem elements are both situated just beneath the pericycle. Both of them develop towards the centre, that is, **centripetally**. The elements of xylem and phloem are mainly the same as in Dicot stems. In stems, the narrow vessels are nearer the centre and the wider nearer the circumference, but in roots this order is totally reversed.

(5) **Pith** occupying the central part consists of big parenchymatous cells with starch.

B. Structure of young Monocot root.

The Monocot roots differ from Dicot roots in the following points :—

(1) The **bundles** of xylem and phloem in monocot roots are **numerous**. The number of bundles in Dicot roots varies from two to five in pairs, hence these roots are described as **diarch, triarch,** etc., according to the number of pairs. The Monocot roots are always **polyarch** as they contain many bundles.

(2) The **pith** is large and persistent which in Dicot roots is soon replaced by the developing xylem.

(3) Rootlets are usually absent, so pericycle is not so useful a layer as in Dicot roots.

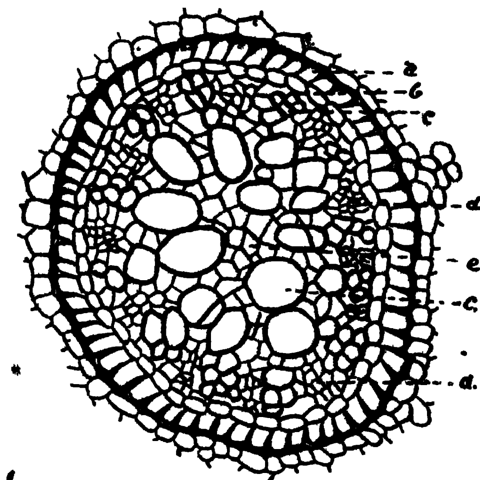


Fig. 155.

Cross section of a Monocot Root. a—Endodermis. b—Pericycle, c—Xylem. d—Phloem. e—Pith.

C. Structure of Gymnosperm root

This resembles the Dicot roots in the following points :-

(1) **Root-hairs** are very scanty. Mostly they are absent.

(2) **Pericycle** is not one-layered but consists of **several layers** of cells. This surrounds the one layered **endodermis.**

LEAVES

A. Structure of Dicot leaf

On cutting a transverse section of a dorsiventral or bifacial leaf which has two well-differentiated surfaces, upper and lower, the following tissues are noticed :—

(1) There are two layers of **epidermis**,—one on the upper surface and the other on the lower. The epidermis may bear stomata and hairs besides ordinary epidermal cells. The stomata are usually confined to the lower epidermis. In vertical leaves, however, stomata are distributed on both sides and in floating leaves, stomata are confined to the upper epidermis. The **cuticle** on the epidermal layer is sometimes well-developed. The epidermal cells are rectangular and in one layer. They are not green but closely arranged.

(2) **Mesophyll** or a green parenchyma lies between the upper and the lower epidermis. The parenchyma is divided into two parts, namely, **palisade** and **spongy**.

The **palisade cells** are elongated and arranged compactly at right angles to the upper epidermis below which they are placed. They are in one or several layers and contain a large number of chloroplasts all regularly arranged along the cell-walls. This arrangement is meant for the protection of the chloroplasts when the sunlight is intense.

The **spongy cells** are just above the lower epidermis. They are in several layers and more or less roundish in form. The chloroplasts in the cells are not so numerous

as in the palisade but are scattered. The cells are loosely arranged with many intercellular spaces between them which are big above the stomata of the epidermis. The big spaces called **respiratory cavities** form communicating

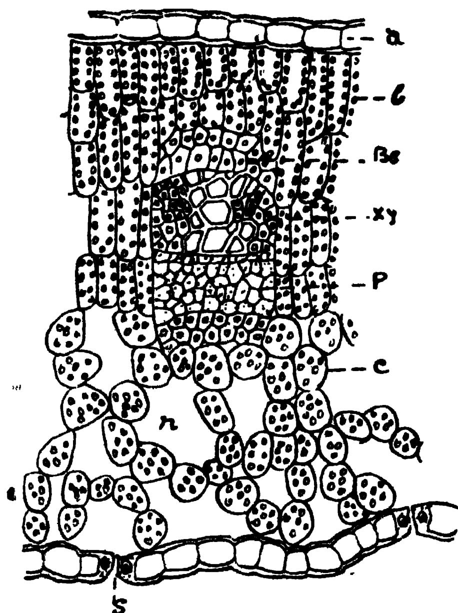


Fig. 156.

Transverse section of a bifacial dicot leaf. a—Upper epidermis. b—Palisade cells. Bs.—Bundle-sheath. xy—Xylem. P—Phloem. c—Spongy cells n—Cavities. s—Stomata.

channels between the air outside and the mesophyll inside. The spongy cells are mainly responsible for carbon assimilation, respiration and transpiration though the palisade cells take part in carbon assimilation also.

(3) **Vascular bundles** appearing between the palisade and spongy parenchyma may be large or small. They consist of **xylem** towards the upper surface and **phloem** towards the lower. Bundles are collateral and also closed. Each bundle is surrounded by a **bundle-sheath** of **parenchymatous cells** which are quite different from the cells of mesophyll.

The section of a leaf taken from the **midrib** shows that it consists of two **epidermal layers** between which lies the **ground tissue** of colourless cells. The **bundles** are in the middle of the ground tissue. They are closed and arranged in the same way as in the other portions of the leaf. Besides **medullary rays** in the bundles, there are two layers of **endodermis** and **pericycle** placed one above the other in order. Thus the section approaches more nearly to the stem-structure.

B. Structure of Monocot leaf.

It differs from the Dicot leaf in the following points :—

(1) **Mesophyll** is not differentiated into palisade and spongy tissues. All the cells, here, are mostly of the spongy type.

(2) There are many **patches of sclerenchyma** occurring here and there or usually between the vascular bundles and epidermis.

(3) The **bundle sheath** usually consists of **sclerenchyma**.

C. Structure of Pine (a Gymnosperm) leaf.

The leaf is triangular differing widely from Dicot and Monocot leaves. The following are to be noticed :—

(1) The single **epidermis** has **thick cuticle** and **sunken stomata**. The hairs are absent.

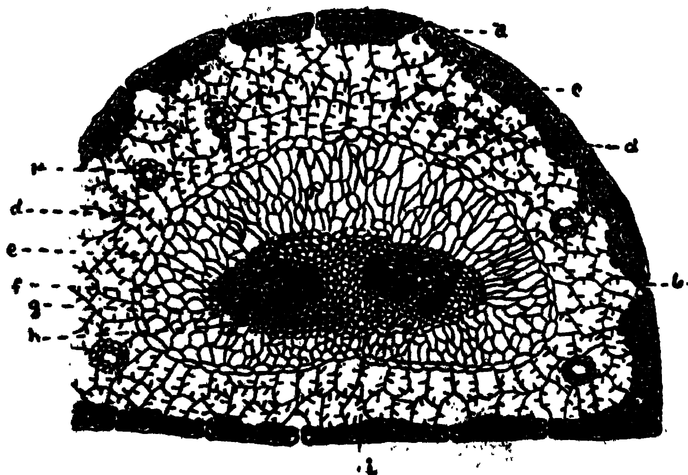


Fig. 157.

Cross section of pine leaf. A—Epidermis. B—Stomata. c—Hypodermis. d—Mesophyll. e—Endodermis. f—Pericycle. g—Xylem. h—Phloem. i—Transfusion tissue. r—Resin duct.

(2) **Hypodermis** consists of **sclerenchymatous fibres** of two or three layers.

(3) Just below the hypodermis there is a number of **resin ducts** scatteredly placed. Each duct is surrounded by an **epithelial layer** which is again surrounded by a **sclerenchymatous sheath**.

(4) The **mesophyll cells** are not differentiated as in Dicot leaves. They are all uniform and provided with peculiar **cellulose projections** on their inner walls.

(5) There is a layer of **endodermis** just beneath the mesophyll.

(6) Next to endodermis is the **many-layered pericycle.**

(7) **Two vascular bundles** lie within the pericycle. They are **collateral** and consist of only xylem and phloem. Xylem faces towards the flat surface and phloem towards the convex surface of the leaf. Cambium is absent.

(8) **Transfusion tissue** lies within the pericycle. This consists of (a) **living albuminous cells with starch and proteids** and (b) **dead tracheideal cells with bordered pits on their walls.**

Summary of Chapter VII

1. **Growing point of shoot.**—There are three layers of cells in the growing region viz. (a) Dermatogen, which divides to form epidermis, (b) Periblem, which divides to form cortex, (c) Plerome, which forms stele.

2. **Growing point of root.**—The three layers are :—(a) Calyptrogen, which forms piliferous layer and root-cap, (b) Periblem, which forms cortex, (c) Plerome, which forms stele.

3. **Dicot stem** consists of the following parts :—(a) Epidermis, (b) cortex, divided into hypodermis, cortex proper and endodermis, (c) pericycle, (d) bundles—each divided into xylem, cambium and phloem, (e) pith.

4. **Monocot stem** differs from the dicot in having undifferentiated ground tissue and numerous vascular bundles.

5. **Gymnosperm stem** differs from the dicot in the following—(a) vessels and companion cells absent. (b) bordered pitted tracheides. (c) sieve plates, lateral. (d) resin ducts in wood and cortex. (e) complex medullary rays.

6. **Fern stem** consists of—(1) epidermis, (2) hypodermis, (3) parenchyma, (4) steles—each with (a) endodermis, (b) pericycle, (c) phloem. (d) xylem. (e) parenchyma.

7. **Selaginella stem** has one or several steles—each is surrounded by air space connected by endodermal cells. Xylem develops centripetally.

Equisetum stem is characterised by cavities in two rings. It agrees broadly with dicot stem.

8. **Dicot root** has the following—(1) piliferous layer, (2) hypodermis, (3) cortex proper, (4) exodermis (5) endodermis, (6) pericycle. (7) xylem and phloem arranged separately (8) pith.

Monocot root differs from the dicot in having more bundles of xylem and phloem and persistent pith.

Gymnosperm root agrees with dicot but the root-hairs are absent and the pericycle is many-layered.

9. **Dicot leaf** consists of (1) upper epidermis, (2) palisade tissue, (3) bundles with xylem and phloem. (4) spongy tissue with cavities, (5) lower epidermis.

Monocot leaf has the mesophyll undifferentiated and the sclerenchyma in patches. **Pine leaf** consists of (1) thick-walled epidermis with cuticle and sunken stomata, (2) hypodermis; (3) resin ducts, (4) mesophyll, (5) endodermis (6) pericycle (7) vascular bundles (two only) (8) transfusion tissue.

Exercise VII

1. Describe the histology of the growing point of a monocot or dicot root.—C. U. 1927, 1913.

2. Describe the structural difference between the growing point of a stem and that of a root. Illustrate your answer with sketches. —C. U. 1929.

3. Describe the structure of a typical dicot stem as seen in the transverse or longitudinal section.—C. U. 1926, 1923, 1922, 1917 1916, 1914, 1912, 1909.

4. Describe, with the aid of a diagram, the microscopical appearance of a transverse section of the stem of a monocot plant.—C. U. 1933, 1924, 1922, 1921, 1920.

5. Describe the morphological appearance of the transverse section of the root of a monocot plant.—C. U. 1925, 1915.

6. Describe the cellular tissue of a typical leaf. Give a sketch and mention the functions of the various kinds of cells in the sketch. —C. U. 1925. 1919, 1912, 1911, 1910.

7. Compare the fibro-vascular bundles in a monocot stem with those in the rhizome of a fern as regards distribution and structure. —C. U. 1917.

(**Hint** :—Both of them are scattered but monocot bundles belong to a single stele while fern bundles belong to many steles. Monocot bundles are collateral and covered by bundle sheaths. (For tissue elements of the bundles consult page 236).

8. Describe the internal structure of a coniferous tree and point out how it differs from that of a dicot.—C. U. 1926.

(**Hint** :—Pine may be taken as the coniferous tree. For the internal structure, stems, roots and leaves are to be described and compared with those of a dicot).

9. Describe, with sketches, the microscopic structure of Equisetum stem as seen in transverse section—C. U. 1929.

CHAPTER VIII

SECONDARY TISSUES

Secondary growth

We have so far the description of all primary tissues and we know how the primary growth is complete. In all herbaceous dicots, the roots and stems do not much increase in thickness as their primary tissues persist all through without undergoing any further change. But in woody shrubs and trees after the completion of primary growth their bodies increase in bulk by secondary growth. This is due to the formation of new tissues owing to the activity of cambium layers which appear as secondary meristems in them. The new tissues are formed both in the intra-stelar as well as in the extra-stelar regions of stems and roots.

A. Intra-stelar secondary growth in stems

We know that the **fascicular cambium** between xylem and phloem is a meristem. This divides and produces new cells which are added to the xylem and phloem. Thus they increase their elements. When secondary growth commences, the primary medullary rays situated between any two fascicular cambium layers divide meristematically and form new cambium layers called **inter-fascicular cambium.** The two kinds of cambium layers now join together to form a complete ring of cambium round the central cylinder.

The **fascicular cambium** of the ring serves two functions :—

(1) It continues the formation of new xylem and phloem as before.

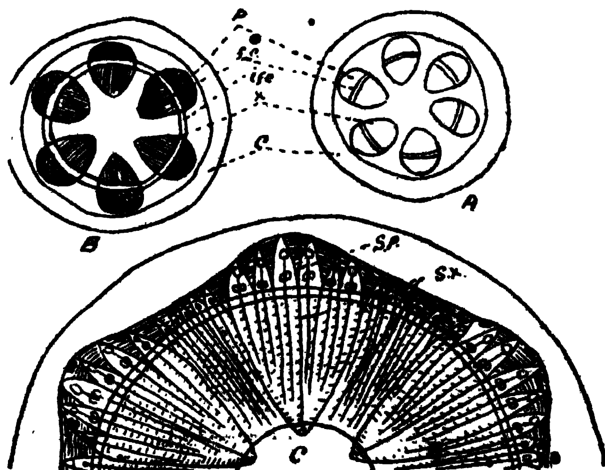


Fig. 158.

Secondary growth in dicot stem. A—Before secondary growth. B—When secondary growth commences. P—Phloem. C—When secondary growth takes place. fc—Fascicular cambium. ifc—Inter-fascicular cambium. x—Xylem. c—Cortex. s. x.—Secondary xylem. s.p.—Secondary phloem.

(2) It produces long parenchymatous cells within the bundles called **secondary medullary rays**. Unlike the primary rays, these newly-formed rays are confined within the bundles.

The **inter-fascicular cambium** serves in the same way the two functions but what is the primary function for the fascicular cambium is secondary to the inter-fascicular one and vice versa. Thus,

(1) It adds parenchymatous cells to the primary medullary rays which becoming elongated in this way extend from pith to the cortex.

(2) It also adds new cells to the xylem and phloem towards their respective sides. These are called **secondary xylem and phloem elements**.

The newly-formed elements of xylem push the primary elements towards the pith which is soon occupied by xylem. Thus by the continual increase of secondary xylem and phloem and the production of secondary medullary rays the stems gradually increase in thickness.

Secondary xylem consists of (1) **pitted vessels**, (2) **bordered pitted tracheides**, (3) **wood fibres**, (4) **wood parenchyma**. Secondary phloem consists of (1) **sieve tubes**, (2) **companion cells** (3) **phloem parenchyma** (4) **phloem fibres**.

In Gymnosperms, secondary growth occurs in the same way. Here, the secondary xylem consists of mostly **tracheids with bordered pits**. The **vessels are absent**. Secondary phloem has **sieve-tubes** and **parenchyma**. The **companion cells are totally wanting**. The sieve-tubes have **lateral walls**.

In Monocots, as the bundles are closed there is no increase in thickness. There is no further growth of the stem, when all the cells finish their individual growth. Secondary growth occurs in some Monocots. (See page 242).

B. Intra-stelar secondary growth in roots.

We know that before secondary growth in roots there are separate xylem and phloem bundles situated just beneath the pericycle. Both of them develop centripetally. Soon the developing xylem bundles meet in the centre and occupy the place previously occupied by the pith. For this reason when primary growth is complete in Dicot roots there is usually the absence of pith.

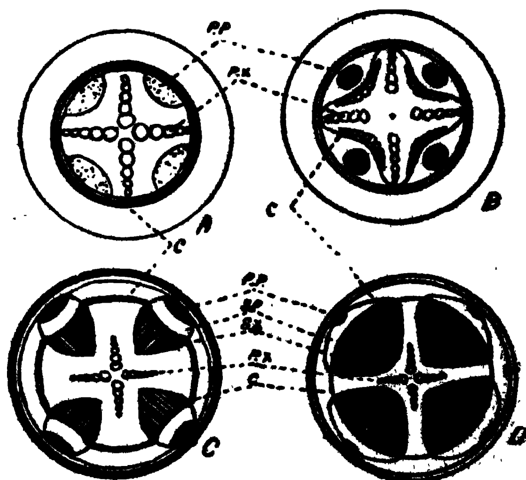


Fig. 159.
A. B, C, D—The successive stages of the secondary growth in Dicot root. p.x—Primary xylem. p. p—Primary phloem. C—Cambium. s. x—Secondary xylem. s. p—Secondary phloem.

When secondary growth commences, the parenchyma lying below each phloem group divides meristematically to form a strip of **secondary cambium**. Similar divisions occur soon in the parenchyma between xylem and phloem. The cells

of the pericycle lying just above the proto-xylem group also become meristematic after divisions and join with other strips,—one formed below phloem and the other formed between xylem and phloem. Thus a wavy continuous ring of secondary cambium is formed. This cambium of root differs from that of stem in being entirely *secondary*. This **wavy cambium** goes on producing secondary xylem on the inner side and secondary phloem on the outer side. Gradually the wavy ring becomes circular as it is active below phloem which is pushed forward. The circular ring of cambium now acts in the same way as in Dicot stems. **Primary** and small **secondary medullary rays** also develop now from the cambium ring.

Annual rings in dicot stems and roots

The meristematic cambium is not uniformly active throughout the year. It is nearly inactive in winter but highly active in spring. The xylem elements formed by cambium in winter are quite different in form and function from those produced in spring. The elements added to the xylem in winter are long, narrow fibres and tracheides. But in spring when the plants work with renewed vigour and roots absorb a large quantity of water the vessels formed are broad and wide. They form **spring wood** while those added in summer or winter form **autumn**

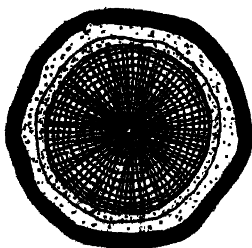


Fig. 160.
Annual rings in mature dicot stem.

wood. Thus every year two distinct different layers of xylem are produced by cambium to form concentric rings which alternate regularly. By counting their number in an old stem its age can be approximately determined. These concentric rings are called **annual rings**.

Duramen and **alburnum**

In old trees the core of the stem or root becomes distinctly differentiated from the peripheral region. The core consists of completely dead wood elements which are highly coloured and strengthened due to the deposition of tannin and other colouring matters on the walls. This is well seen in old trees of *babla*, *kantal*, *sal*, *ablus*, etc. This is called the **heart-wood** or **duramen**. The peripheral part of the stem through which sap is now transferred from the roots is called **sap-wood** or **alburnum**.

Extra-stelar Secondary growth

A. Formation of cork

When secondary xylem and phloem elements continually increase in number due to the activity of the cambium they push those cells which stand in their front in order to make room. Pressure at last falls on the outermost tissue, the epidermis, which is thus stretched and ruptured. This stimulates the formation of another secondary meristem of cambium in the extra-stelar region. This is known as **phellogen** or **cork cambium**. In most of the stems it arises from the hypodermis but sometimes it takes its origin in the superficial layers of cortex proper. The new cambium now goes on dividing and forming new cells on its

both sides. Those cells formed on the inner side are big, parenchymatous green cells of **phelloderm**. The cells produced on the outer side are at first living and thin-walled.

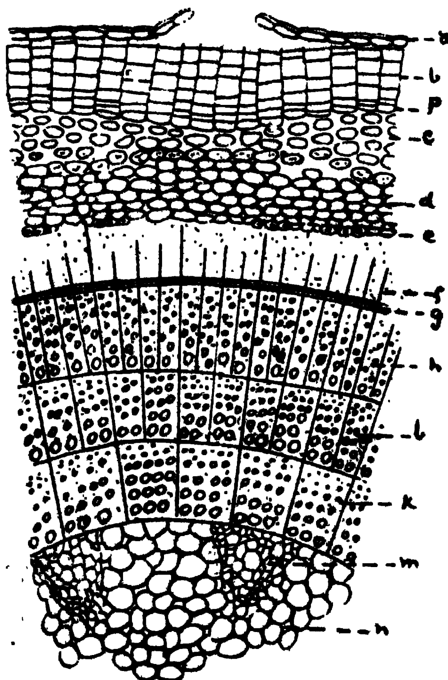


Fig. 161.

Cork formation in a mature dicot stem. a—Ruptured epidermis. b—Cork. p—Cork cambium. c -Phelloderm. d - Cortex cells. e—Phloem f—Secondary medullary rays. g—Cambium. h, i, k—the three successive rings of xylem. m—Primary wood. n—Pith.

Gradually, their walls become suberised and they are arranged so closely that the intercellular spaces are absent in them. They are rectangular in form and ultimately

they lose protoplasm and become dead. These cells form a dead tissue which is known as **cork** or **periderm**.

Suberin being impervious to water, when the suberised cells of cork form a compact barrier, epidermis does not get any supply of water or food from the internal tissues. Thus cut off from nourishment, epidermis dies and is included into the dead tissue of cork. In many stems, the phellogen does not persist long. Soon it becomes inactive and dead. In roots, the phellogen takes its origin in the pericycle.

B. Formation of Bark

When the first-formed phellogen becomes inactive and dead, it is replaced in most dicot trees by a new phellogen which takes its origin in the deeper layers of cortex. In the same way, this new phellogen produces a new cork layer which cuts off its connection from the internal tissues. As a result of this, all the tissues outside the new phellogen die off and are added to the first-formed periderm. Soon the phellogen becoming inactive and dead is also transformed into periderm. The elements of secondary xylem and phloem are still on the increase due to the activity of cambium so there is continual internal growth and consequent thickening of stems. Another phellogen arises to produce another layer of periderm which does not allow any further absorption of food or water from the internal tissues. Thus all the tissues lying outside dry up and become dead. This process continues till the whole portion of cortex, pericycle and sometimes even phloem

is converted into a dead mass called **bark**. Bark thus consists of a number of **superposed periderm layers**. It implies all the dead tissues lying outside an active phellogen.

Bark may form in patches as in *peyara* where it is called **scale bark**. In *am*, *babla*, it forms complete rings so it comes away in sheets. This is called **ring bark.**

Functions of cork or bark

(1) It protects the inner tissues from the attacks of animals or insects, etc., disturbances of weather, external injuries and fungal growth.

(2) It diminishes loss of water by transpiration and evaporation.

(3) It checks loss of heat.

(4) It removes waste products when it falls off from the tree.

Formation of lenticels

The cork or bark produced by the activity of phellogen forming a thick continuous ring closes the stomata making respiration and all interchange of gases impossible So special structures originating just beneath the stomata are produced by phellogen. They consist of a few rows of loose, powdery cork cells so that gaseous interchange between the plant and the external air becomes possible.

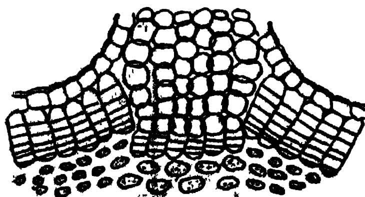


Fig. 162.
Lenticels.

They appear as so many brown or white specks on the surface of the mature stems and aerial roots, as *jaba*, *simul*, *kea*, etc.

Tylosis

When the vigorous growing parenchymatous cells surrounding the vessels press the latter hard they push the middle lamella of the pits inwards and fill the cavity of the vessels by developing in them **sac-like cells** which continue to grow. These are known as **tyloses** which though are frequent in the vessels of the heart-wood are also found to occur in the sap-wood. They heal up the wounds of the vessels when they are thus inflicted and serve for the storage of starch. Such a growth of parenchyma within the cavities of vessels is called **tylosis**.

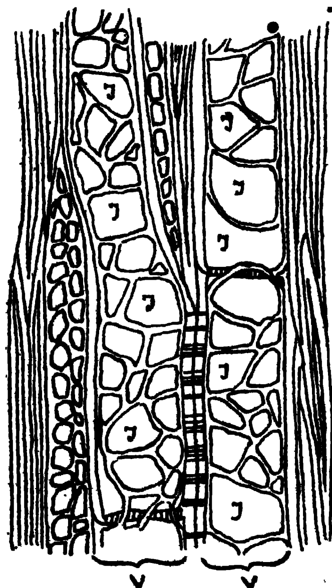


Fig. 163.
T—Tyloses.
V—vessels.

Leaf-fall

In an articulated leaf, when it is about to fall, some cork cells form a layer across the base of the leaf-stalk. Outside

this layer and towards the leaf another layer of parenchymatous cells called **abscis layer** is formed. The cells of this layer separate from one another owing to their middle lamella becoming mucilaginous. The cells may also become disorganised when the bundles of the petiole now find themselves too feeble to bear the burden of the whole leaf which then falls off. The exposed ends of the bundles are covered by a mucilaginous substance secreted for this purpose.

Healing of wounds

When the flowering plants or Pteridophytes are injured in any part of their organs, the uninjured layer of cells lying just below the wounds develops a phellogen and then a new cork layer in order to protect the injured surface. Sometimes, when the plants are woody, instead of producing the cork cells, a mass of parenchymatous cells of so-called **callus** in the form of swollen growths arises in the uninjured cells bordering the wound. These cells covering the wound form cork. If the wounds be so deep as to reach the cambium of the stems, fresh patches of cambium may be formed by the callus. Laticiferous cells or vessels, when wounded, may heal up their wounds by the coagulation of latex at the points of injury.

Summary of chapter VIII

1. **Secondary growth** indicates the formation of new tissues owing to the activity of cambium layers resulting in the increase in thickness of the organ where the cambium is active.

2. **Intra-stelar secondary growth in stems.**—Inter-fascicular cambium strips are formed between the fascicular cambium strips. Both of them join to produce a continuous circular ring. This produces new xylem, phloem and medullary rays. Some of the rays are within the bundles and others extend up to cortex.

3. **Secondary growth in roots.**—New cambium is formed when the parenchyma below phloem, between xylem and phloem and above xylem becomes meristematic. This cambium is at first wavy but gradually becomes circular by pushing the phloem bundles forward. It then acts as in stems.

4. **Annual rings.**—Cambium being not uniformly active in the year produces spring wood in the spring time and autumn wood in other seasons when the activity is much less marked. These two types of wood form two rings every year called annual rings.

5. **Duramen and alburnum.**—The core of the mature stem or root is called duramen while the surrounding wood in which the sap flows is called alburnum.

6. **Formation of cork.**—Internal pressure of new xylem and phloem causes the rupture of epidermis and the formation of phellogen in the cortex. The phellogen produces cells outwards and inwards. The outward growing cells soon become suberised and dead. They cut off the connection of inner tissues with their outlying cells which also become dead. These dead cells in layers above the phellogen form cork or periderm.

7. **Formation of bark.**—This process is the same as in the case of cork but it consists of a number of superposed periderm layers formed by a series of phellogen.

8. **Lenticels.**—These are loose cork cells formed by phellogen in the stems for the interchange of gases.

9. **Tylosis.**—This is a growth of parenchyma in the cavities of vessels in the form of sac-like cells.

10. **Leaf-fall.**—This takes place by the formation of cork cells and a layer of parenchyma called absciss layer.

11. **Healing of wounds.**—This occurs by the formation of phellogen or callus surrounding the wounds.

Exercise VIII

1. What is understood by secondary growth ? What is its significance ? How does a dicot stem grow in thickness ? Is the method of growth the same in dicot and monocot plants ?—C. U. 1929, 1916, 1912.

2. Describe the structure of the transverse section of a dicot stem in which secondary thickening has just commenced.—C. U. 1918.

3. Describe the structure of the transverse section of the stem of a dicot which is three years old.—C. U. 1928.

4. Explain the formation of ring-like markings in the wood of a dicot. Why they are absent in the stem of a monocot ?—C. U. 1914, 1913.

5. What is cork ? How is it formed and in what part of the plant-body ? When leaves fall, how is the wound closed ? What is liable to happen if the wound is not closed ?—C. U. 1930, 1909.

6. What is bark ? How is it formed ? What are the functions ? —C. U. 1931, 1928, 1920, 1917, 1912.

7. What are lenticels ? How are they formed ?—C. U. 1933.

PART III

PHYSIOLOGY

Physiology is that division of Botany which deals with the various actions which a plant carries on as a living organism. This usually enquires into the nature of food materials absorbed by the plant, the method of absorption, the result of absorption, growth, reproduction, etc.

There are three important branches into which Physiology is divided :—

(1) **Physiology of Nutrition** includes those processes in which food materials after absorption are transformed into the substance of plants.

(2) **Physiology of Growth** and **Movement** deals with the changes of forms of plants and the manifestations of peculiar movements.

(3) **Physiology of Reproduction** deals with the separation of those parts of plants by which new individuals are produced.

CHAPTER I

FOOD OF PLANTS

Composition of plants.—It is evident that all the elementary substances which are found in plants are contained in the food which they absorb. If we can learn what chemical elements the plant substance contains, we can easily determine the nature of the plant food.

The composition of plants can be determined by (*a*) chemical analysis, or (*b*) by water-culture method.

(*a*) Chemical analysis.

A fresh plant is at first weighed and then dried in the sun for several hours. The dried body is re-weighed. The heavy diminution of weight is due to the loss of water which makes more than three-fourths of the total weight of the plant.

All living plants or organs of plants contain a large quantity of water in them. Though it may vary in different plants or parts of plants, the quantity of water present in any member is never less than forty per cent. of the whole body. In some succulent plants as *mala*, *kapi* etc., water forms ninety per cent. of the total substance. Thus, water is the most important of the materials of which the plant-body is made up. It plays an active part in the absorption of food. An active protoplasm is quite incapable

of doing any work unless it is thoroughly saturated with water. Water also saturates the cell-walls, starch grains and other carbohydrates. It is abundantly present in the cell-sap. When chemically analysed, it is found that hydrogen (H) and oxygen (O) are the chemical elements which go to form the compound, water.

When water is driven off from the plant, the dry substance remaining is ignited in a closed vessel so that the gases given off during the combustion can easily be collected. If we test the gases they are found to consist of carbon dioxide, water and other compounds of nitrogen and sulphur. The elements composing all these compounds are found to be hydrogen, oxygen, carbon (C), nitrogen (N) and sulphur (S).

The combustion is allowed to continue until the residue left behind is 'ash' which suffers no further change even if it be burnt repeatedly. On chemical analysis of the ash the elements invariably present in it are found to be phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K) and iron (Fe). Besides these, sodium (Na), chlorine (Cl), silicon (Si) are also detected in some plants. Sometimes traces of iodine and manganese are also found.

The essential elements of plant food.

If several other plants be analysed chemically in the same way as above, we find that the following ten elements are common in all plants. These elements occur not only in the composition of the plant body but also in the food of plants. As without them their body can never be formed these elements are essential for the life of any plant.

They are :—

(1) **Carbon.**
(2) **Hydrogen.**
(3) **Oxygen.**
(4) **Nitrogen.**
(5) **Sulphur.**
(6) **Phosphorus.**
(7) **Potassium.**
(8) **Calcium.**
(9) **Magnesium.**
(10) **Iron.**

Uses of the elements in plants.

The ten elements essential in building up the body of the plant enter into the chemical composition of the substances of which the tissues or cells of the plant consist. For the formation of cellulose, starch and other carbohydrates,-carbon, hydrogen and oxygen are necessary. The three elements form these compounds by combining in different proportions. In the composition of the living substance of the plant, i.e. protoplasm, sulphur and nitrogen are required in addition to carbon, hydrogen and oxygen. Protoplasm contains all the elements which are found in the proteid substances. Besides the above five elements, phosphorus is also present in the protoplasmic substance of the nucleus though it does not appear to be an essential constituent of protoplasm in general. Iron is an important element necessary for the development of chlorophyll. As regards the remaining three elements, potassium, calcium, magnesium, they are found to be important for the formation and proper distribution of carbohydrates.

(b) Water culture method

This is an experiment by means of which we can prove that plants grow healthily when they are cultivated in water in which certain salts containing the essential elements have been dissolved.

We know that plants require raw materials for their nutrition and they absorb them from their natural sources. Unlike animals, they have to take their food in a liquid form. They can drink but can not take solid food. The raw food materials which they absorb from the soil are always taken in when they are completely dissolved in water. The soil in this respect is only necessary to supply those salts which contain the indispensable elements of plant food. Artificially we can select those salts and dissolve them in different proportions in distilled water. A **culture solution** is thus prepared, containing all the food elements which the green plants require. Any plant allowed to grow with its roots immersed in the solution and without being connected with the soil can thrive so long as the food materials are available from the solution. We must take particular care in the selection of salts in which all the nine elements (carbon excepted), without omitting a single one of them, are present. In our experiments we are to observe also the results of the omission of any particular element from the solution.

A good **normal solution** should have the following composition.

	Distilled water (H_2O)	1 litre.
1.	Potassium nitrate (KNO_3) ...	1 gramme.
2.	Sodium chloride ($NaCl$)	·5 gramme.
3.	Calcium sulphate ($CaSO_4$) ...	·5 ,,
4.	Magnesium sulphate ($MgSO_4$) ...	·5 ,,
5.	Calcium phosphate Ca $(PO_4)_2$ ...	·5 ,,
6.	Iron. chloride (.Fe_2Cl_6) ...	a few drops

N. B.—It is to be noticed that the quantity of salts in the solution is very small in comparison with the volume of water in which the salts are dissolved Sodium chloride, is not essential. Though there are plants which flourish with it others do not require it and so their growth is not affected by its omission.

Expt. Select several well-grown seedlings of the same species, e.g. pea, all with well-developed roots Preference should be given to those

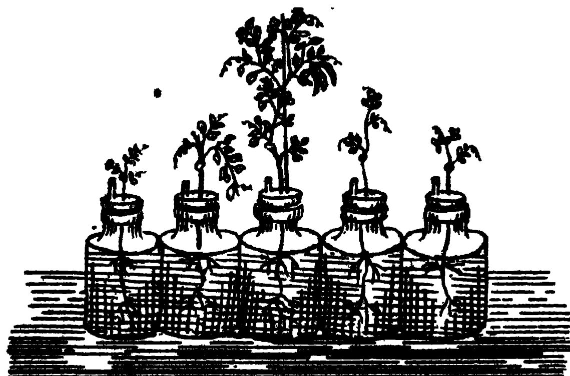


Fig. 164.
Water culture experiment. Only the middle bottle contains normal solution.

which are nearly of the same height and weight. The roots are then thoroughly washed in distilled water. Fill up several wide bottles fitted with corks with acidulated distilled water to a little below the neck. Corks are split so that the seedlings can be suitably fixed. Place in one of the bottles all the salts of the normal solution as given above and fill up the remaining bottles with a solution from which one or the other of the essential elements be wanting. For example, in place of potassium nitrate, sodium nitrate may be used or potassium phosphate in place of calcium phosphate. In one bottle, iron may be totally omitted. In this way when these bottles are filled with different solutions, introduce the seedlings through the split corks in such a way that the roots are all dipped into the solution. Care should

be taken that the seedlings are supplied with air and the bottles are kept under proper light and temperature.

After allowing the seedlings to grow for several weeks it is found that growth is normal or healthy only in that seedling where roots are immersed in the normal solution.

In other cases, wherever there is omission of a single element, growth is hampered. For instance, the plant growing without potasium nitrate is stunted in its development. That which grows without iron is not green in colour. In the same way, the growth of other plants without the normal solution is not healthy.

The normal solution contains only nine elements. The tenth element, carbon, is altogether absent in the solution. The plant in the normal solution thrives well and produces even flowers and seeds, although carbon is not offered to it. Let us enquire into the source from which the large percentage of carbon found in all plants is derived.

Sources of the food elements

Carbon —In our previous experiment we have noticed that though carbon is conspicuous by its absence in the normal solution, the growth of a plant in it is very healthy. On the other hand, chemical analysis of the plant tells us that half the dry weight of a plant, that is, the weight of a plant after removing the water which it contains, is found to be of carbon. This carbon the plant gains from the atmosphere which surrounds the green parts of plants. This is present in the carbon dioxide always available in the atmosphere. So long as there is sunlight, all parts of a plant possessing chlorophyll are capable of absorbing carbon dioxide from the air. In the case of submerged

water-plants where they are not in contact with the atmosphere, this carbon dioxide is taken from water in which it remains dissolved. In a very few cases, carbon is absorbed from the soil where it is found in the form of carbonates.

Oxygen is an important element next to carbon as it is present in large proportion in the dried substance of the plant. It always enters into the composition of most of the mineral salts obtained by the plants. It is derived from the water absorbed by the roots and from carbon dioxide taken in by the green parts of plants.

Hydrogen is a gas like oxygen with which it combines to form water. So it is derived mostly from the water absorbed by the roots. It is present in a very few mineral salts from which it is obtained.

Nitrogen is present in much smaller proportion in the dry weight though it occurs chiefly in the proteid substances of plants. As air is a mixture of oxygen and nitrogen mainly, it is always present in air. But green plants can not absorb free nitrogen from the air. It is derived from the nitrogen-containing mineral salts and ammonia found in the soil. Insectivorous plants derive nitrogen from the captured insects.

The remaining **six elements** are all derived from the mineral salts containing them. From sulphates and phosphates, plants can obtain sulphur and phosphorus. Potassium, calcium, magnesium and iron are present in the mineral salts as their metallic radicals.

Air, soil and water are mainly the three sources from which the majority of plants derive all the required food materials. (Consult chapter I, Morphology)

Air as a source of plant food. Air is a mechanical mixture and not a chemical compound. It consists of free oxygen and nitrogen mainly. Besides water vapour, trace of ammonia and a few other unimportant gases, a small quantity of carbon dioxide is also present. Thus, in 100 vols. of air the following are the different proportions of oxygen, nitrogen and carbon dioxide.

Nitrogen—	79·00
Oxygen—	20·96
Carbon dioxide—	·04
Total volume of air—	100·00

Of the different gases in air, only oxygen and carbon dioxide are of great service to the plant. Plants require oxygen for respiration and carbon dioxide for photosynthesis. We shall deal with these processes later.

Soil, another source.—The soil consists of many organic and inorganic particles aggregated together in different proportions. When a plant thrives well in a soil, it indicates that the soil contains all the mineral substances the plant is in need for its growth. The organic materials of the soil are derived from the remains of animals and plants which are converted into 'humus' by Bacteria, moulds etc. Soil containing humus is able to absorb and retain water. This property as well as the presence of nitrogen in it is of great importance for plant growth. The particles of the soil when examined under the microscope are found to be separated from one another. The minute gaps left are filled up with air. The presence of air in the inter-spaces of the soil particles is highly beneficial to the plants as the

roots can then freely respire. In marshy places, the air is replaced by water called **free water** of the soil. Free water in the soil always hampers the growth of ordinary plants. Again, each particle of soil may be surrounded by a thin film of water, called **hygroscopic water**, held there by capillary action. This water dissolves the mineral salts which are soluble in water. Thus, a soil suitable for the healthy growth of a plant should have the following properties.

(1) Inter-space filled with air.
(2) Necessary mineral salts.
(3) Hygroscopic water.
(4) Bacteria for nitrification.
(5) Humus.

Summary of Chapter I

The ten essential elements entering into the composition of plants are—carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus potassium, calcium, magnesium and iron. Their presence in the plant-body can be proved by chemical analysis or by water-culture method. The first six elements form protoplasm ; iron forms chlorophyll while the other six go to form carbohydrates.

Soil and air are the two natural sources from which plants derive all the required elements. Air contains oxygen, nitrogen, and carbon dioxide mainly. Soil contains organic and inorganic matters.

Exercise I

1. Describe briefly how would you investigate the nature of the elements necessary for plant life by the water culture method.—C. U. 1931, 1922, 1909.

CHAPTER II

ABSORPTION OF SALTS

Minerals.

It is a known fact that by long and continued cultivation, the land becomes gradually impoverished and manures have to be used for the restoration of fertility. The gradual sterile condition of the soil is due to the absorption of the minerals by plants. The elements required by the plants are not present as such in any soil, but in the form

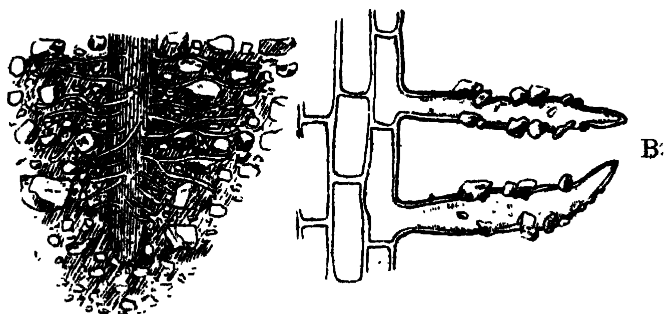


Fig. 165.
Root-hairs closely attached to the soil particles. Only two hairs of A are magnified in B.

of minerals. We have seen before that plants can not absorb salts from the soil unless they are completely dissolved in water. It is for this reason that water is absolutely necessary for the life and growth of a plant.

Root-hairs.

Though roots are the organs of absorption, the parts which are actually active for this function are the root-hairs, each of which is uni-cellular, thin-walled, and full of protoplasm with a central vacuole. The hairs appear a

little behind the apex. With the growth of the roots they soon disappear, but are constantly replaced by others in the same relative position. When they pass between the soil particles they adhere to them so firmly that they are brought into close contact with the films of the soil-water in which the minerals remain dissolved.

Process of dissolving the minerals

Most of the salts in the soil such as nitrates, sulphates, chlorides, carbonates, etc., are soluble in the hygroscopic water. (1) Some insoluble salts of lime, magnesia, etc., become soluble when they are exposed to the action of air and water rich in carbonic acid. (2) Carbon dioxide, evolved as the result of the respiration forms with water carbonic acid, which helps in rendering insoluble salts soluble. (3) When the root-hairs come in direct contact with the soil particles, they excrete a kind of acid which helps in dissolving some insoluble minerals. (4) Organic acids and carbon dioxide are also produced when the organic portion of the soil undergoes changes and carbon of the soil is oxidised. (5) Various lowly plants such as Fungi, Bacteria are always found to be at work in breaking down dead organic matters and converting them into nitric acid and other compounds of nitrogen when nitrogen becomes available for the use of higher plants. The process of converting the nitrogen of the organic matter into ammonia and the successive changes which the ammonium compounds undergo by the action of Bacteria to form at last soluble nitrates is called **nitrification**.

Osmosis :-

It is a common observation that dry raisin *(kismis)* placed in a vessel of water for a few hours will swell considerably.

Again when these swollen raisins are transferred to a strong sugar solution they shrink. This swelling and shrinking are due to osmosis, a physical phenomenon.

The main principle of osmosis is :—

When two liquids of different densities are separated by any permeable membrane, a current will be set up between the liquids as a result of which a large amount of weak solution will pass through the membrane and a small amount of strong solution will come out. This will continue so long as the liquids are not of the same density. The passing or diffusion of the weak liquid is called **endosmosis** while that of the strong liquid is called **exosmosis**. As the weak liquid diffuses faster, the endosmotic current is stronger than the exosmotic current. Owing to the strong endosmotic current, considerable pressure is set up within the membrane. This is known as **osmotic pressure**.

Expt. 1. Selecting an elongated stout potato tuber a cavity is bored length-wise in it in such a way that the cavity reaches nearly the other end. Care should be taken that the tuber is not bored through. Taking a thin slice from the closed end. shape the tuber so that it can stand erect in a shallow dish of water a few inches deep. On filling up half the cavity with strong sugar solution it is noticed that after a few hours the liquid not only fills up the cavity but overflows.

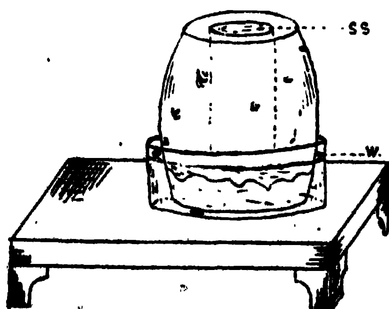


Fig. 166.

Potato tuber with a cavity in it placed in a basin of water. S. S.—Sugar solution. W—Water in the basin.

Expt. 2. One end of a wide glass tube is covered with parchment while the other end is corked. Through a hole in the centre of the cork a narrow tube passes, the free end of which is in close connection with a manometer tube containing mercury. The wide tube is now filled with strong sugar solution coloured with eosin and is placed in a basin of water. After connecting the narrow tube with the manometer and pressing the cork with the narrow tube into the sugar solution the level of mercury in the free limb of the manometer is marked. After a few hours it is noticed that the level of mercury gradually rises. This proves that the diffusion of water into the wide tube is faster than that of the sugar solution into the basin of water which thereby becomes slightly red in colour.

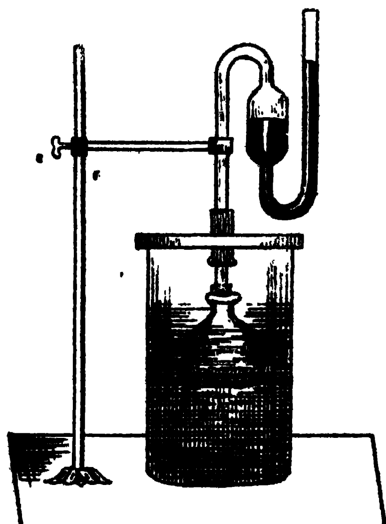


Fig. 167.
Apparatus for measuring osmotic pressure.

Rot-hairs absorb by osmosis

When the root-hairs adhere very firmly to the soil particles, each of them is surrounded by the hygroscopic water with the various salts of the soil dissolved in it. This solution outside the root-hairs is weaker than the dense cell-sap present within the vacuole of the hairs. The organic acids, acid salts and sugars usually present in the cell-sap are believed to have a strong attraction for water. The cellulose wall together with the living layer of proto-

plasm (primordial utricle) acts as the permeable membrane separating the two liquids—one strong inside and the other weak outside. Consequently a large amount of weak salt solution passes into the cavity of the hairs. Similarly only a minute quantity of the cell-sap passes out. The quantity of the acid sap given out by the root-hairs during exosmosis is just sufficient to act upon certain insoluble salts and to render them soluble. Endosmosis being far greater than exosmosis, considerable pressure is exerted on the wall of the hair, thus bringing about a very tense or turgid condition of the cells.

The primordial utricle plays a very important part in the process. Controlling the osmotic process it allows water to come in but refuses to let out certain substances of the sap. Thus, there is much difference between osmosis taking place in living cells and that occurring through a dead membrane which is purely a physical process.

Selective power of plants

The protoplasmic layer, having a great influence on osmosis, can easily select those salts which the plant requires and reject others which are injurious to it. All plants growing on the same soil do not absorb the same salts and in the same proportion. Different plants have different needs. Cereals such as wheat, maize, etc., take from the soil less than half as much nitrogen, lime and potash as crops like potato, beet, etc. do. Grasses are more active in the absorption of silicon, cocoanut of common salt (Nacl), pulses of lime, orange of calcium etc. It is for this reason that farmers usually raise crops with similar needs alternately

with others on the same field instead of in succession. This alternation is called **rotation of crops**.

Conditions for root-absorption

(1) All the salts offered to the roots and demanded by the plant should be thoroughly dissolved in the hygroscopic water.

(2) The soil must contain free oxygen so that the roots and root-hairs respire easily. The respiration is effective in giving out carbon dioxide which helps the solution of insoluble salts.

(3) Suitable temperature of the air surrounding the plant as well as of the soil or solution in which the plant is growing, is an essential condition, as with the rise of temperature absorption increases. But if the temperature is too high or low absorption is hampered.

(4) The salt solution should be very dilute. Rapid absorption occurs if the difference of densities of the two liquids be very high, but if the salt solution is denser than the cell-sap, osmosis will take place in the opposite direction. In that case the root-hairs instead of being turgid wilt.

(5) The cell-sap should have such substances in it which have strong attraction for the water outside the hairs.

(6) The presence of too large an amount of salts impedes absorption. It is for this reason that though the soil of marshes, bogs, etc., appears to be extremely fertile, very little of the materials it contains is directly available as plant-food.

Summary of Chapter II

1. Minerals in the soil supply all the elements excepting carbon as required by the plants.

2. Root-hairs are uni-cellular, their protoplasm contains a vacuole with cell-sap.

3. Process for dissolving the minerals.—Most of them are soluble. The insoluble salts are made soluble by the action of carbonic acid produced in different ways.

4. Osmosis.—Two solutions of different strength when separated by a membrane cause a flow through it so long their strength is not equal. Weak solution flows faster.

5 Application of osmosis.—Of the two solutions the denser one is the cell-sap in root-hairs and the weaker is the solution of salts outside the root-hairs of which the protoplasm serves as the intervening membrane.

6. Selective power of plants.—According to the needs of plants the protoplasm of root-hairs absorbs salts and rejects others thus regulating osmosis.

7. Conditions for root absorption.—(1) All salts must be dissolved, (2) Oxygen, (3) temperature, (4) dilute salt solution, (5) osmotic substances in the cell-sap, (6) small amount of salts in the soil.

Exercise II

1. Describe the structure of a root-hair and describe the process of obtaining raw food materials from the soil by an ordinary green plant. Name the chief food elements of plants.—C. U. 1933, 1932, 1931, 1927, 1926, 1924, 1918, 1815.

CHAPTER III

MOVEMENT OF SAP

Turgescence

We have seen before that due to endosmosis a large quantity of hygroscopic water with dissolved salts enter into the root-hairs. This absorption continues according to the presence of osmotic substances which have strong attraction for water. When the cells are thus filled up to their utmost capacity, a considerable pressure is set up in the cells which thereby become highly tense or turgid. This tense condition of the cells due to osmotic pressure regulated by the influence of the living protoplasmic layer is called **turgescence**. The stiffness of the cells may be compared to that of an inflated cycle-tube under the pressure of air pumped into it. The wall of the turgid cell distended to a great extent being elastic exerts a pressure on the solution inside. Thus, the turgescence is maximum when the osmotic pressure is balanced by the internal pressure exerted by the stretched cellulose wall.

Turgescence is not solely due to physical causes. The protoplasm there has a regulating influence over the passage of water in and out of the cells. The quantity of osmotic substances present in the cells depends on the activities of protoplasm. These substances are being continuously formed in all young cells at or near the growing point of an organ and in most other cells where chemical changes are going on.

Hence, these cells with the osmotic substances present, constantly absorb water from the neighbouring cells by osmosis. Protoplasm is saturated with water and a stretching force is exerted on the wall which bounds it. Fresh cellulose particles manufactured by protoplasm are now laid on the stretched wall and the extension of wall is made permanent.

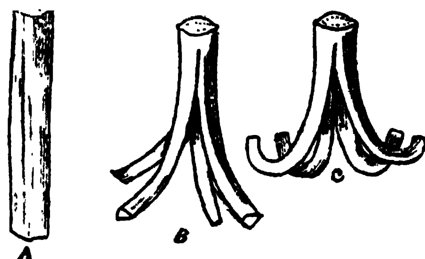


Fig. 168.
Puin stem. A—A portion of the stem. B—When the portion is cut into four longitudinally. C—The cut stem is placed in water.

Expt.—A fleshy *puin* stem of a few inches in length is cut longitudinally into several parts. Before the stem was cut, the inner cells were much compressed by the stress and strain of the outer strengthening tissue surrounding the inner ones. As a result of the cut, the inner cells freed from the pressure outside expand and hence the parts become widely separated. If the cut stem is now placed in water, for an hour, it is found that the parts become more widely separated and their inner surfaces more convex than before due to the considerable absorption of water by the cells and the consequent stretching of their cell-walls. Again, if the cut stem is placed in strong sugar solution, the turgid cells collapse. The sugar solution attracts water from the cells when their cell-walls shrink due to the reduction of the internal pressure. The parts are no longer separated but are closely attached to each other.

Uses of turgescence

(1) The turgid condition of cells is necessary for growth.

(2) Turgescence is also necessary for the various kinds of movements of the different parts of plants when they adapt themselves to the different conditions of their environment.

(3) Herbaceous and aquatic plants have to depend much upon their turgid cells for the rigidity which enables them to maintain their position in the medium in which they live.

(4) Turgescence is one of the causes which drives water with the dissolved salts into the upper regions of plants.

Root pressure.

In the living cortical cells chemical changes are going on continually as a result of which osmotic substances are formed in them. They are in constant need of water and so like root-hairs they have the capacity of imbibing water by osmosis. The turgid root-hairs being closely attached to the cortical cells, cell-to-cell osmosis takes place between them. The flaccid root-hairs again become turgid by the absorption of fresh water from outside. In the same way, each cortical cell repeats the process, alternately becoming turgid and collapsing, so that the water moves at last to the last layer of cortex lying around the xylem vessels. These cells of cortex become so turgid that it is impossible for the cell-walls to resist the pressure exerted by the sap. The hydrostatic pressure, thus set up, forces the sap into the xylem vessels in which it ascends in the form of a column. **This pressure noticed in the root which forces water upwards in the form of a**

column is called the root pressure. The passing of sap into the vessels from the cortical cells is not due to, osmosis as the vessels are all dead and the conditions of osmosis do not exist. The passage of sap into the vessels is due to filtration.

Root pressure is not uniform throughout the day, nor is it uniform in all seasons of the year. In spring time, when active growth is going on in the plants, enough water comes out when the stem of a plant is cut a little above the soil. This is known as the **bleeding of plants.**

Experiment for measuring root pressure.

Cutting the stem of a pot plant say *dopati*, a little above the ground early in the morning and connecting it with the short arm of a U-tube by means of rubber tube the level of mercury is marked after filling the tube first with water and then with mercury. As there is continual absorption of water from the soil and consequently there is, the upward pressure of water, the mercury column in the long arm of the U-tube rises. Thus the root pressure can be measured.

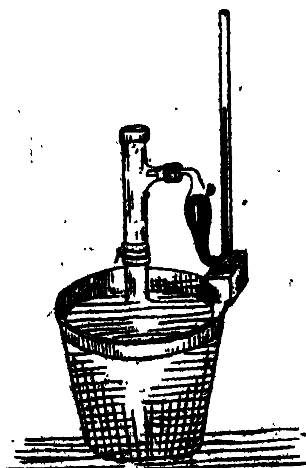


Fig 169. Apparatus measuring root pressure.

Transpiration.

Water is imbibed from the soil as a carrier of the mineral salts demanded by the plant. The salts are dissolved in thousands of times their weight of water. We have seen

that when the solution enters the wood-vessels of the root, it is forced upwards by the root pressure. It then ascends into the trunk and branches of the plant through the vessels till it reaches the veins of the leaves. From there it makes its way to the mesophyll cells which become turgid. Though some water in these cells is used for the building up of protoplasm and other foods of plants, the greater part of the water is not required further, so it escapes from the turgid cells by evaporation and diffuses through the stomatal openings to the external air. **The diffusion of surplus water in the form of water vapour through the stomatal openings into the external air is known as transpiration.** Land plants usually possess more stomata on the lower surfaces of their leaves. Consequently, more water is evaporated from the lower surface than from the upper surface of the leaves.

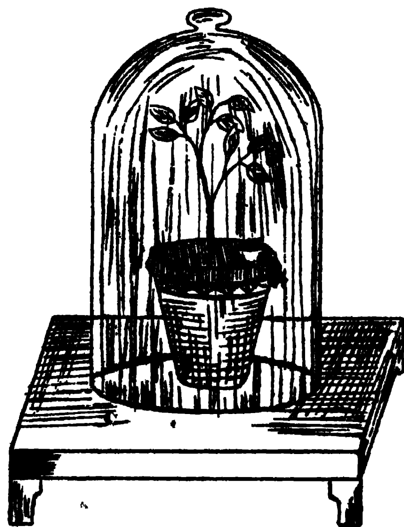


Fig. 170.
To prove transpiration by bell-jar experiment.

Expt. 1. When a small plant say *beli*, growing in the sun, is covered by a bell jar, we find that minute drops of water are deposited on the inner side of the jar. These drops are formed by the condensation of water vapour given off by the plant as the result of transpiration.

We can estimate the amount of water given off by the plant during twenty-four hours by the following method :—

The soil on which the small plant is growing is covered completely by a large piece of tinfoil so as to prevent evaporation from the soil. Filling a small cup with dry calcium chloride and weighing it in the balance carefully. it is placed on the tin-foil. Calcium chloride has the property of absorbing water readily. The plant with the cup on the tin-foil is placed under a bell jar for twenty-four hours, the edge of the bell-jar being sealed with vaseline. The cup, reweighed after the experiment, is found to have gained much weight due to the absorption of water given off by the covered plant. It is estimated that ordinary leaves of *dopati* usually give off one gramme of water per day.

Expt. 2. A few sheets of cobalt paper are prepared by soaking filter papers in cobalt chloride solution and warming them dry. The cobalt paper, when dry, is blue in colour but when exposed to moist air or when breathed upon turns red. Two such dry pieces of paper are placed on the two surfaces of a leaf. They are then covered with sheets of thick glass so that no air can come in contact with the papers. After a few hours it will be found that the paper placed on the lower surface has turned redder than the other, thus proving that the lower surface gives off more water vapour.

Transpiration and evaporation compared

There is much difference between transpiration and ordinary evaporation. Transpiration is not a process of simple evaporation. Evaporation may take place in the presence or absence of light but transpiration is generally impossible if there is no light. Evaporation is the conversion of liquid water into vapour. It is a purely physical process. Transpiration is the passage of this vapour through the stomatal openings into the external air by diffusion.

So the amount of water given off by transpiration is never equal to that given off by evaporation from the same area of the leaf surface. This can be experimentally proved by taking two freshly cut shoots of the same plant, one of which is placed on the table, while the cut-end of the other is connected with water in a vessel. Within a few hours it is seen that the shoot on the table wilts as there is evaporation without absorption ; but the other being supplied with water makes its cells turgid, the loss of water being made good by the fresh supply of water from the vessel. So long the protoplasm is active and is in connection with water from outside the second shoot remains fresh and turgid.

Transpiration current

When the leaves transpire, the escape of water from the mesophyll cells increases the density of their cell-sap and and thus renders the cells flaccid. They are now capable of sucking up fresh water from the veins of leaves which are continuous with the vessels of stems and roots. The vessels, in their turn, receive water from the turgid cortical cells. The cortical cells become filled with water which travels from the root-hairs due to the continuous endosmotic action. So the water lost from the leaves is always replenished by the ceaseless absorption of water from the soil by the root-hairs. Thus, a continuous flow of water is brought into play from the roots in the soil to the green leaves in the air. **The escape of water from the leaves by transpiration and its suction by the root-hairs always maintain an ascending current in the vessels. This is known as the transpiration current.** The current may be interrupted when the surrounding air is very hot and consequently

the transpiration is vigorous. But the loss of water from the leaf surface being greater than the suction of water from the soil, the leaves become limp and droop.

When the water ascends, it flows mainly through the cavities of xylem vessels and tracheides which are occupied partly by water and partly by bubbles of air at a very low pressure. A small portion of water passes through the walls of the woody elements of plants. As the current ascends only by the xylem of plants, transpiration is not affected and the leaves above remain vigorous if a ring of cortex down to the cambium of a branch be incised and removed. But if the incision be deep enough to reach the xylem vessels the leaves will wither and droop. In the trunk of trees the water flows through the sap-wood which when wounded affects transpiration to a great extent. In many places old trees are noticed which have lost their heart-wood. The well-known *siddha-bakul* of Puri is an instance of such tree.

Causes of the ascent of water

It is a matter of interest to know how the water ascends to the uppermost regions of trees 400 feet or more high in direct opposition to the action of gravity. Though various theories are put forward to explain what causes this ascent, they do not seem to be quite satisfactory. Undoubtedly osmosis and transpiration play an important part in the ascent. The continuous loss of water by the transpiring leaves causes a pull on the water in the woody elements. The low pressure in the vessels is also taken as one of the causes. Some attribute it to physical phenomena such as, atmospheric pressure and capillary action of the narrow tubes of the vessels, although they are quite insufficient to

explain it. Many ascribe the ascent to the vital activity of protoplasm, but this theory also can not stand as it is found that a poisonous solution which would kill the protoplasm can ascend in the vessels when offered to the roots.

To measure the rate of the transpiration current by potometer.

Expt. A branched glass tubing about half an inch in diameter is clamped vertically and is connected horizontally with a long graduated capillary tube bent at right angles at the free end. Both the tubes are filled with water and the bent end of the capillary tube is dipped into a small basin of coloured water. Each of the divisions of the graduated tube corresponds to a cubic centimetre of water. A freshly cut vigorous leafy shoot is now introduced into the branch of the glass tubing through a perforated rubber cork which covers the mouth of the tube. Care must be taken to cut the shoot below water and attach it to the glass tube in such a way that no air bubble can enter the vessels of the shoot. By lifting the capillary tube-end out of the water of the vessel and by replacing it quickly a bubble of air is allowed to enter the tube. When the leaves of the shoot transpire, the water travels in the horizontal thermometer, the rate of which can easily be determined by the slow movement of the bubble. The different results obtained can be compared when the experiment is performed (1) in direct sunlight,

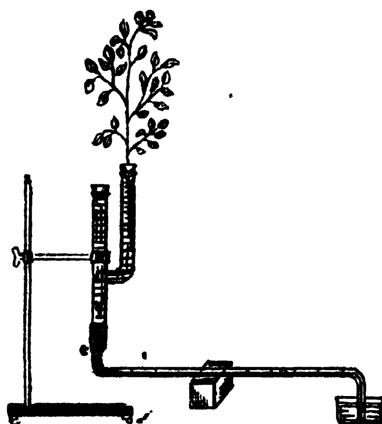


Fig. 171.
Potometer.

(2) on any dull day, (3) with all the lower surfaces of the leaves of the shoot smeared with vaseline.

N. B. The above experiment is also a measurement of absorption of water.

To prove that the amount of water transpired is nearly equal to the amount of water absorbed by the root.

A vigorously growing small plant is introduced with its roots through a perforated air-tight india-rubber cork in a stout long bottle filled with water and having a graduated narrow branch-tube as shown in the figure. The branch is divided into centimetres. Before the experiment the whole apparatus is weighed in the balance. It is re-weighed after transpiration has taken place for a few hours and consequently the level of water in the branch-tube sinks. The difference in weights representing the loss of water due to transpiration is found to correspond with the amount of water absorbed by the roots which can be determined by the difference in the levels of water in the graduated branch-tube.

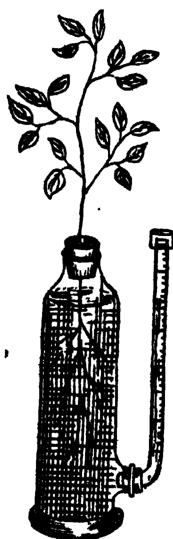


Fig. 172. To prove that the water transpired is equal to water absorbed by roots.

Organs of transpiration.

Leaf is the chief organ of transpiration where the emission of water vapour goes on entirely through the stomata. For this reason, this emission is called **stomatal** or **internal transpiration** for, the escape of water vapour takes place over all the internal surfaces

abutting on the intercellular-spaces into which the vapour has been given out by the mesophyll cells, specially those of the spongy parenchyma. Transpiration also takes place, though to a limited extent, through all the epidermal cells of the transpiring organs. This is called **cuticular or external transpiration.** This diminishes with the increase of thickness of the cuticular layers of the epidermis till it becomes nil. Thus, in plants having a thick cuticle, cork or wax on the outer surface, the loss of water by transpiration is not rapid. This is well-observed in *chalkumra* fruits which do not suffer from great loss of water as they have the cuticle covered by wax or bloom (see page 227)

Mechanism of stomata for regulating transpiration.

We know that the guard cells which surround the stomatal opening differ from the rest of the epidermal cells by possessing chloroplasts. The guard cells, thus, can assimilate for themselves and form new organic substances which pass into their cell-sap to increase the density. This takes place when the stomata are exposed to light and hence the chloroplasts become active. The guard cells with the concentrated cell-sap in them now absorb water by osmosis from the neighbouring cells and become turgid. As the side of any guard cell bounding the pore is more rigid than the other, it offers more resistance to stretching when endosmosis takes place. Now, the more turgid the guard cells become, the more their outer walls stretch than their inner walls so they become convex on the outer side and concave on their inner side towards the pore. So long as sunlight is present and the guard cells are turgid the stomata open. Hence, transpiration is possible



when the stomata open in light. At night, when assimilation stops, water is withdrawn from the cells where the osmotic substances are not formed. Consequently, the outer walls shorten more than the inner and hence the guard cells collapse, tend to become straight and close the pore between them. Stomata, by opening and closing, can thus regulate the transpiration of the plant.

Conditions affecting transpiration.

(1). Humidity of air.—The drier the air, the more vigorous is the transpiration. On the other hand, when the air is moist, the transpiration is checked. The withering of plants or the drooping of leaves on a very hot day is a common observation. If a plant with leaves, drooping from too great a loss of water, be transferred to an atmosphere saturated with moisture, the plant soon becomes fresh and turgid.

(2) **Temperature.**—The capacity of air for holding moisture increases with the rise of temperature. At a particular temperature the air goes on absorbing moisture till it becomes saturated. So, the farther the air is from the saturation point, the more vigorous is the transpiration.

Temperature of the soil in which the roots of the plant are embedded has an influence on the transpiration as it is noticed that warmth of the soil increases the amount of water vapour given off by the leaves.

(3) **Light.**—Apart from the warmth accompanying light, the stronger the light, the greater the transpiration. We have noticed before the effect of light on the opening and closing of the stomata which have much influence on

the transpiration. That light increases transpiration can be proved by transferring a plant from darkness to sunshine.

(4) **Windy day.**—Transpiration is markedly increased in a windy day, as continued renewal of the air surrounding the plant has much effect on the rate of evaporation.

(5) **Mechanical disturbances of weather.**—It is observed that violent shaking of the plant due to the mechanical disturbances caused by weather namely a storm, stimulates protoplasm to such an extent, that it allows transpiration to increase resulting in the drooping of leaves.

(6) **Number of leaves and stomata.**—As leaves are the transpiring organs, and as transpiration occurs through the stomata, the more the leaves and their stomata are in number, the more active is the transpiration. With the increase of the surface of the transpiring organs, transpiration increases.

Importance of transpiration.

(1) A large quantity of water is taken from the soil in order to absorb the salts. The greater portion of this water when transported to leaves as a carrier of salts, is useless. Transpiration is the means by which plants remove this surplus water.

(2) As some portion of the water carried in the leaves is utilised for the construction of nutritive substances of plants, transpiration helps this construction.

(3) As transpiration causes a pull on the water and sets up the sucking action in the roots, there is a constant supply of water and raw food materials in the leaves and other parts of the plants.

(4) Transpiration keeps the plants cool, for the greater part of the energy of sun's heat falling on the plants is dissipated in converting the liquid water into vapour. Only a small part is left behind to raise the temperature of the plant-body.

(5) Transpiration maintains the turgidity of the tissues which is of great value to the growing cells.

Contrivances for checking excessive transpiration.

(1) Plants reduce their leaf surface. Sometimes, the whole leaf is reduced to a mere spine, as in *phanimansha*, or scale as in *jhau*.

(2) The number and size of stomata are much reduced. They may be deeply sunken as in *pine*, or they are covered by waxy substances as in *akanda*.

(3) During the dry season some plants drop their leaves entirely to prevent loss of moisture by evaporation as *amra*, *simul*, etc.

(4) Leaves may have coverings of cuticle, resin or hairs as found in *chita*, *bans*, *ak*, etc.

(5) Leaves are rolled up as found in *fern*.

(6) To avoid full rays of intense light leaves place themselves vertically.

(7) The fleshy leaves of *patharkuchi*, *ghritakumari*, etc. store up every drop of water they can get when rain falls and live sparingly on it during the long periods of drought.

(8) Palisade parenchyma is very fully differentiated.

Transpiration and exudation compared.

(1) Exudation is the process of giving out water in liquid form and not in the form of vapour through water-stomata, hairs, terminations of vessels, epidermis, etc. This takes place when roots absorb more water than is given out by leaves and when the conditions for transpiration become unfavourable. (2) Transpiration removes pure water but the water given off by exudation is never pure. The water contains salts which are deposited on the organs when water is evaporated. (3) Transpiration usually takes place so long as light is present and the stomata are open but exudation may take place both in light as well as in darkness. The drops of water, looking like dew-drops in the early morning on the leaf-apices of *ghas*, *kachu*, etc., are exuded by the plants. The emission of sugary liquid from the incised stems of *khejoor*, *tal*, etc., is another example of exudation.



Fig. 173. Exudation experiment.

Water stomata are openings for the excretion of water in the form of drops. Though large in form, they look like ordinary stomata but unlike them their guard cells, from which protoplasm vanishes after growth, have no power of closing the pore. Thus they remain always open. They develop usually at the ends of veins where they may be associated with hydathodes as found in the leaves of *dholapata*, *kachu*, *durba*, etc.

Expt. By fixing a growing leafy shoot in one arm of a U-tube a little quantity of water and then mercury are poured into the other arm. Leaves are then found to exude water in the form of drops.

Summary of Chapter III

1. Turgescence is the tense condition of cells due to osmosis regulated by the protoplasm. It is useful for growth and movements. It drives water upwards.

2. Root-pressure is the pressure in the root due to which water is forced upwards in the form of a column of water.

3. Transpiration is the process of removal of surplus water from the leaves in the form of vapour during day time. Evaporation is the giving off of vapour. Transpiration is evaporation when the removal is controlled by protoplasm.

4. Transpiration current—The escape of water from the leaves by transpiration and the suction of the same by the root-hairs maintain an ascending current in the vessels called transpiration current. There are many causes of the ascent of water. The organs of transpiration are mainly the leaves from which the vapour passes through stomata or cuticle.

5. Mechanism of stomata for regulating transpiration.—The green guard cells produce organic substances in light, and thus increase the density of their cell-sap. They then absorb water by osmosis from the neighbouring cells and become turgid. As their outer wall is thinner than the inner one, the turgescence causes the formation of a pore between the two guard cells of a stoma.

6. Conditions favouring transpiration :—(1) Temperature (2) Light, (3) Humidity of air, (4) Renewal of air, (5) Disturbances of weather, (6) Large number of stomata.

7. Importance of transpiration.—(1) It removes surplus water, (2) It helps the construction of food, (3) It drives water upwards with which food is drawn, (4) It keeps plants cool, (5) It maintains turgescence.

8. Transpiration and Exudation.—Transpiration removes water in the form of vapour but exudation removes it in the form of drops. When the conditions for transpiration become unfavourable xudation takes place.

Exercise III

1. What is meant by turgescence? How is it maintained and what is its use to the plant? What factors modify it?—C. U. 1923, 1921, 1910.

2. What is root pressure? How do you determine and measure it?—C. U. 1917, 1913.

3. Describe some experiment to prove that the life of a plant can not be maintained unless water is supplied to the roots.—C. U. 1932.

4. What is transpiration? Explain fully how a plant gets rid of its surplus water. What structures of the plant are concerned in the process? Mention the necessary conditions of transpiration.—C. U. 1931, 1929, 1927, 1919, 1915, 1912.

5. What are stomata? Describe their structure and functions. How do they behave when the atmosphere is dry?—C. U. 1926, 1921, 1916.

6. Why are some plants able to keep their leaves during the winter whilst others always lose them?—C. U. 1916.

(**Hint**:—In winter, absorption can not cope with transpiration. Plants able to reduce their transpiring surface can keep their leaves. For the contrivances of checking excessive transpiration, consult page 301.)

7. Two freshly cut shoots A and B are taken; the cut end of A is placed in water and the shoot B is allowed to lie on the table. After a couple of hours A is found to be as fresh and rigid as before while B has become limp. Explain the cause of difference.

(**Hint**:—The water lost by transpiration in A is compensated by the continuous absorption of water, hence A remains fresh. B becomes limp as there is no compensation of the loss.)

CHAPTER IV

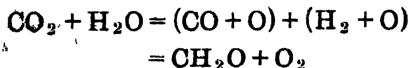
ASSIMILATION

Carbon assimilation or photo-synthesis.

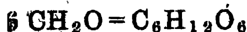
We know that the salts absorbed by the roots contain all the essential elements excepting carbon and that the salts are all in-organic compounds. We will now consider the question how a green plant absorbs carbon from air and how the inorganic compounds are converted into organic compounds out of which cell-walls, protoplasm, etc. are formed. Carbon, the most important of all the elements of nutrition, is absorbed from air by the green leaves in the form of carbon dioxide gas. **Carbon assimilation consists in the absorption and decomposition of carbon dioxide taken from the air and of water taken from the soil to produce at last some form of a carbo-hydrate out of the elements of decomposition.** This process takes place in all green plants under the influence of sunlight and hence this is known as photo-synthesis, (photos—light, synthesis—putting together).

The process.

All green parts of plants absorb carbon dioxide gas from the surrounding air in presence of sunlight and suitable temperature. The gas passes into the intercellular spaces by means of stomatal pores in the case of the green leaves. From these spaces it diffuses into the spongy parenchymatous cells of the mesophyll and is dissolved in the cell-sap. The mesophyll cells are all provided with chloroplasts which serve to catch certain rays of sunlight, specially those of the red and blue colour. By the energy absorbed the plastids are enabled to do the work of decomposing both carbon dioxide and water of the cells. The carbon dioxide (CO_2) is decomposed into carbon monoxide (CO) and oxygen. A portion of water (H_2O) present in the mesophyll cells is also decomposed into the nascent hydrogen (H_2) and oxygen. The nascent hydrogen, thus set free, unites at once with the carbon monoxide to form a simple carbohydrate compound known as **formic aldehyde** (CH_2O). As a result of condensation, a soluble carbohydrate of the nature of **sugar** ($C_6H_{12}O_6$) is produced at last. This can be represented in the following equations :—



$$CO_2 + H_2O = (CO + O) + (H_2 + O)$$
$$= CH_2O + O_2$$
$$6\,CH_2O = C_6H_{12}O_6$$



(Formaldehyde) (sugar)

Though we assume these changes to take place in the green parts of plants, it is quite certain that nothing so simple actually occurs there. However, we are sure so far that after the absorption of carbon dioxide, sugar or in some

cases starch is the direct product of assimilation and that oxygen comes out freely from the plants as the result of the process.

The process of carbon assimilation is the most important of all physiological phenomena, as on this the lives of all plants and animals in the world depend. Herbivorous animals eat plants and the former are eaten by carnivorous animals and by men. To go further, we are all living directly or indirectly as parasites on plants.

To prove that oxygen is given off during carbon assimilation.

Expt. 1. Some water plants e.g., *patashaola* or *jhanji* are put in a sunny place in a large glass vessel of ordinary water which always contains some carbon dioxide in solution. A funnel. with a short stem is allowed to cover the plant in such a way that the funnel is wholly under water. A test-tube is then filled with water and inverted over the stem of the funnel. When the plants are thus exposed to sunlight, bubbles of gas are given off from them in a constant stream. The gas is collected in the test-tube displacing the water. Now, after taking away the test-tube from the stem carefully, if a glowing match is plunged into it, the match will at once rekindle proving the presence of oxygen gas in the test-tube.

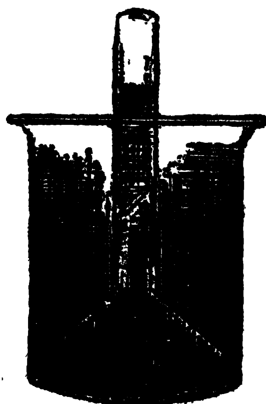


Fig. 174.
To prove the evolution of oxygen in photosynthesis.

If the vessel be covered with a black cloth so as to exclude light it is observed that after a time the bubbles do not come out.

To prove that starch can not be formed without CO_2

Expt. 2. A seedling growing in normal culture solution is kept in darkness for two days so as to make it starch-free. The whole is introduced into a wide mouthed jar containing a little caustic potash solution. The jar is then corked tightly and the edges are sealed with vaseline. Through a hole in the cork the stem of a funnel passes. The funnel is filled with caustic potash sticks. Air enters the jar through the hole but all the CO_2 the air contains is absorbed both by the sticks and the potash solution. When the seedling is thus exposed to light for a day, no starch is found within the leaves. But, if a similar apparatus be arranged without using the potash solution and the sticks, starch is found to be formed within the leaves.

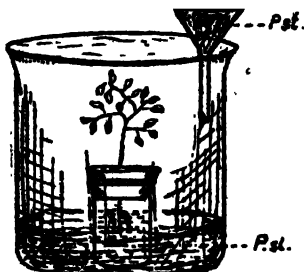


Fig. 175.
To prove that starch is not formed without CO_2
Pst—Potash sticks.

To prove that green parts produce starch in light.

Expt. 3 After keeping a plant in the dark for a day a leaf is taken before sunrise and made colourless by means of warm alcohol. Thus bleached, the leaf is treated with iodine solution but it does not turn blue showing thereby that the leaf is free from starch. After covering another leaf on the plant with a piece of tinfoil in which a letter has been cut out as in the figure, the plant is placed in the sun. After a few hours the covered leaf is plucked, boiled in water and then placed in alcohol until it becomes colourless. The leaf is then treated with iodine solution when it is found that it is turned bluish only in those parts which received light through the cut-area of the tin-foil, the whole of the covered portions remaining unchanged. It is clear, therefore, that starch has been formed in those parts only which were exposed to light.

To prove that chlorophyll is required for starch formation

Expt. 4. The above expt. 3. is repeated with a leaf of *patabahar* (Panax) in which the leaf is partly green and partly white. After the treatment with iodine solution it is found that only those parts which were green become blue, the white parts remaining unaffected. This proves that the presence of chlorophyll is necessary for starch formation,

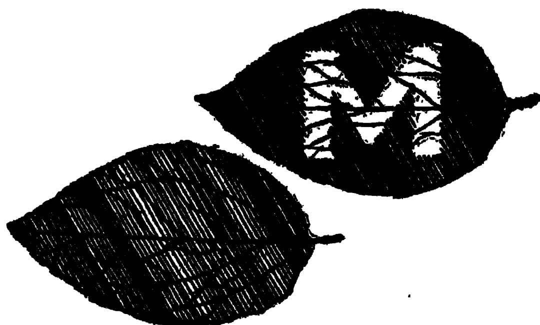


Fig. 176.
To prove that green parts produce starch in light.

Conditions necessary for carbon assimilation.

From the above experiments we are in a position to conclude that the following are necessary for the formation of starch :—

(1) Carbon dioxide, (2) Light, (3) Chlorophyll, (4) water, (5) presence of stomata, (6) slight degree of heat.

Though, we are in the dark about the use of **potassium salts**, we are sure that their absence greatly affects the process.

To prove by Moll's experiment that carbon assimilation can not take place (1) without CO_2 and (2) without light.

A leaf attached to a plant which has previously been kept in darkness for two days is introduced through a split cork into a bottle

containing a little potash solution. When the edges of the cork are smeared with wax, the bottle is kept in its position for a day. When thus sufficiently exposed to light, the leaf is removed, decolourised and then tested with iodine solution. It is found that the leaf does not turn blue showing there is no starch.

Another experiment, with a different leaf on the same plant, is arranged in the same way after keeping the plant in darkness for two days, when the previous experiment is over. The bottle now contains

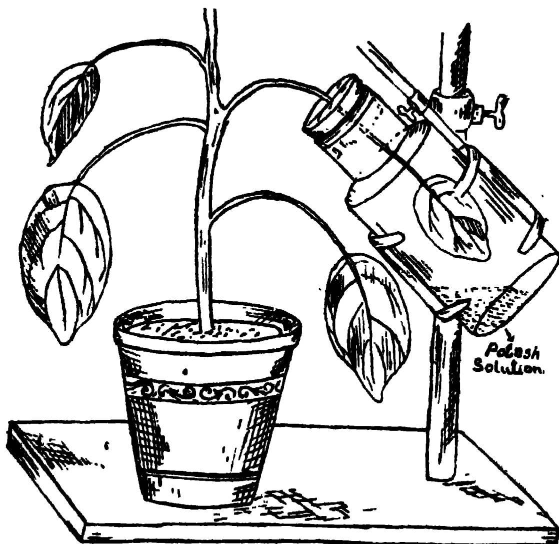


Fig. 177.
Moll's experiment.

a little water instead of potash solution and it is covered with black cloth. After sufficient exposure to light, when the leaf is tested as above, it is also found to contain no starch as the leaf did not get light.

A third leaf on the same plant, which has been kept in the dark for two days after the previous experiment, is put in the same way in the bottle containing a little water but the bottle in this case is not covered. When the leaf is sufficiently exposed to light, it is tested by iodine solution to show that it now contains starch.

To prove that starch formed in the daytime is removed from the leaves at night.

Keeping a plant in sunlight for a day, half of one leaf is cut off in the evening, leaving the remaining half attached to the plant. The half cut off is treated in the same way as in the exp. 3, page 308. The iodine test proves the presence of starch in this portion. Next morning the other half of the leaf is plucked and when treated in the same way as the first half, is found to contain no starch which proves the removal of starch from the leaf during the night.

Chlorophyll

We know that only the green parts of plants assimilate carbon. Total parasites, Fungi, etc., are devoid of chloroplasts and hence they can not assimilate carbon. The green pigment, chlorophyll, is developed within the protoplasmic plastid. Both the pigment and the plastid are useful for the purpose of assimilation as one becomes useless without the other. For the development of chlorophyll the conditions necessary are :—

(1) **Light,** (2) **slight degree of heat,** (3) **air** and (4) presence of **iron compounds** in the cells.

Chlorophyll is a complex substance consisting of carbon, hydrogen, oxygen and nitrogen but not iron though it is required during the development. Chlorophyll is insoluble in water, acids and alkalies but soluble in alcohol, ether and chloroform. The chlorophyll solution is green by transmitted light but blood-red by reflected light. This property of chlorophyll is known as fluorescence. If a beam of light passes through the solution and then through a prism, the spectrum formed is found to be interrupted by seven dark spaces or bands in the different colours of the spectrum,

representing the absorption by chlorophyll of those particular rays of light which are missing in the spectrum. We thus know that **chlorophyll has the power of absorbing a large amount of red rays, some blue and violet rays and a few of the green and yellow rays**. Chlorophyll is readily decomposed by bright light in the presence of oxygen. The products of decomposition are xanthophyll (yellow) and carotin (orange red).

If a potato plant be grown in darkness, it becomes pale yellow in colour due to the development of a yellow pigment called **etiolin** in the plastids of the cells in the place of chlorophyll into which the etiolin may become converted when exposed to light. But if the temperature is very low the etiolin remains unchanged even though light is admitted. Thus, pale sickly plants are called **etiolated**, when they suffer from the want of light. Etiolated plants are characterised by their slender and much elongated stems with small, pale yellow leaves in which spongy and palisade cells are not differentiated. They have their vascular bundles and sclerenchymatous tissues much reduced. t

Again, plants suffering from the absence of iron in their food become pale green or **chlorotic** in condition. But chlorotic plants can be given the normal green appearance by the supply of iron.

Light.

The energy which enables a green plant to decompose such stable compounds as carbon dioxide and water is derived from the rays of the sun absorbed by the chloroplasts. To reduce carbon dioxide to carbon monoxide by heat, a temperature of not less than 1300° C is required

but this reduction is done in the green plants at ordinary temperature of the air. Light, thus, is the chief source of energy which after absorption and storage in potential form is utilised for the decomposition. Sunlight consists of seven different rays of different colours, viz., **violet, indigo, blue, green, yellow, orange and red**. These are well-seen when a beam of sunlight passes through a prism and the spectrum is received on a white screen.

Of these rays, the **red is the most active in promoting carbon assimilation**. The next active rays are orange and yellow. Thus, when a green plant is covered by a double-walled bell-jar containing any red solution between the walls and is exposed to light for a few days, the leaves are found to contain abundant starch by iodine test. But, if the same plant be now covered by the bell-jar containing any blue solution between the walls, starch can not be found by iodine test.

Nitrogen assimilation

With the assimilation of carbon, plants produce in their green parts carbohydrates, from which cellulose, starch, etc. are formed. It is very difficult to follow the process leading to the assimilation of nitrogen and the elaboration of the nitrogenous substances. Nitrogen, one of the most important food elements, is the chief constituent of **proteids** from which protoplasm, the most important part of plant substance, is formed. Most green plants obtain nitrogen from the nitrates in the soil. They are soluble in water and hence they can easily be taken in by the root-hairs. Ammonium compounds, when offered to the roots are converted into nitrites and then into nitrates. When

the solution containing salts of nitrogen are transferred to the leaves, assimilation occurs there in the presence of chloroplasts and light, as a result of which nitrogenous substances of the nature of **amides** and **oxalate of potash** are formed. The potash oxalate, reacting with the calcium salts, forms calcium oxalate found abundantly in many plant-tissues. The amides combine with sulphur and give rise to proteids as a result of further elaboration.

Special methods of Nitrogen assimilation

(a) In leguminous plants.

When the roots of plants of pea family are examined, they are found to be covered with many small tubercles each of which is filled with many oval, unicellular bodies called **bacteroids**. These minute organisms or bacteria produce the tubercles by their active growth in the cortex of the roots. They take free nitrogen from the air contained within the soil and build up this nitrogen into compounds. The nitrogen-compounds are supplied to the leguminous plants which in their turn give carbonaceous compounds to the bacteria. Thus, the two plants grow in such a way that by their association both of them derive benefit. This sort of association of two organisms in a common life is called **symbiosis**. Another bacterium (Pseudomonas) grows symbiotically on the roots of Cycas (Gymnosperm).

In this connecion it may be mentioned here that certain minute fungal plants grow on the roots of higher plants in such a way that both of them are mutually benefitted by such union. This kind of symbiosis is called **mycorhiza**.

(b) **In epiphytes, parasites and saprophytes**

They differ from the green plants in their mode of nutrition. They have been fully dealt with in chapter I, Morphology.

(c) **In insectivorous or carnivorous plants**

(1) **Bladder-wort or Utricularia** (*Jhanji*).—This is a submerged water-plant growing in quiet waters. It has no roots. The leaves and branches are dissected into many fine parts on which many green bladders appear which are the traps of the plant. The mouth of each trap is surrounded by a few hairs. It is closed by a valve or trap-door which opens inwards by a push from outside so that small insects cannot get out of it once they have entered the bladder. Thus imprisoned, the small animals die there and when their soft parts decay, they are absorbed by the plant. (See fig 7).

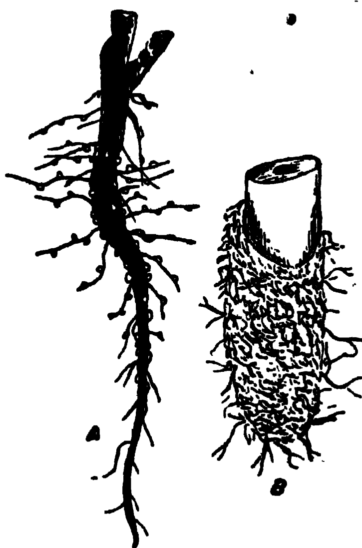


Fig. 178.
A—Tubercles on *kalkasinda* root.
B—Fungal growth on roots showing mycorhiza.

(2) **Drosera or Sundew.**—The leaves of this herb bear stalked tentacles at the end of each of which there is a sticky fluid which looks like a sparkling dew-drop when sunlight falls on it. It is for this reason that the name sun-dew

has been given to the plant. The shining drops allure small insects to alight on the plant. Soon their legs and wings stick to the gummy fluid which holds them tight, however much they struggle to get out of the trap. On the other hand, their desperate struggle has the only result that other tentacles move towards the animals and cover them



Fig. 179.
Sundew plant (a Madras specimen). A - plant. B—Tentacles.

up. Thus held fast, the animals die there and are slowly digested by a kind of fluid secreted for that purpose. When the digestion is complete, the tentacles again become straight, ready to entrap new insects.

The specimens of sundew plants found in Burdwan, Shillong, etc. have spathulate leaves.

(3) **Nepenthes or pitcher plants.**—This plant has the leaves formed like pitchers with a small red-coloured lid

attached to one side of the mouth of each pitcher, half filled with digested fluid which smells like honey. The mouth is slippery and just beneath this there are many downward-pointing hairs. An insect attracted by the lid takes its sit on the mouth, descends to get the honey below, slips into it and is then drowned in the liquid. When the insect is thus killed, its softer parts are gradually digested by the leaves. (See fig. 60)

The specimens of this plant are found in Burma and also in some parts of Assam.

Transference of assimilated food

We know that the xylem portion of the bundles is used for the transport of the ascending sap. In woody plants of advanced growth, the heart-wood never takes part in the conduction which occurs through the new rings of sap-wood. After assimilation when carbohydrates and amides are built up in the mesophyll cells, they pass in solution to the various parts of the plants. The living protoplasm makes use of this as food substance. Many of the soluble compounds are used to form insoluble substances which are stored in special cells as reserve food for future use. Transference takes place at first by cell-to-cell diffusion. It is very rapid when the substances are conveyed through the phloem, specially the sieve-tubes. Usually, nitrogenous substances pass through the seive-tubes while the elaborated carbohydrates are distributed through the phloem parenchyma and the parenchyma of the ground tissue. In this way the elaborated matters are soon transferred to the growing regions or to the special storage cells.

Summary of Chapter IV.

1. **Carbon assimilation** or photo-synthesis is the process of absorption of carbon dioxide and decomposition of carbon dioxide and water under the influence of light. Carbon dioxide is taken from air and water from soil.

2. The process of carbon assimilation—Carbon dioxide is decomposed into carbon monoxide and oxygen while water is decomposed into hydrogen and oxygen. Carbon monoxide mixing with hydrogen forms formaldehyde which gradually is converted into sugar.

3. Conditions of carbon assimilation :—(1) Carbon dioxide (2) Light. (3) Chlorophyll (4) Water (5) Stomata (6) Heat.

4, **Chlorophyll**—For its development light, heat, air, and iron are required. It contains carbon, hydrogen, oxygen and nitrogen, It is soluble in alcohol. The solution is fluorescent. It absorbs many red rays. In its place etiolin is formed when a plant is grown in darkness. Etiolated plants are pale yellow in colour. Due to the absence of iron, plants become chlorotic.

5. **Light**—It consists of seven rays of which red rays are most active in promoting carbon-assimilation.

6. **Nitrogen assimilation**—The sap containing nitrogenous matters produce, after assimilation by chloroplasts and light, amides from which proteids are formed.

7. Nitrogen assimilation by **leguminous plants**—The root tubercles contain bacteroids which, supplying nitrogen to the leguminous plants in exchange of carbonaceous food taken from the plants, live symbiotically with them.

8, **Insectivorous plants** absorb nitrogen from the insect-bodies they capture. They have different adaptations for capturing insects in the different species. *Bladder-wort* is a common insectivorous plant of our climate.

Exercise IV

1. What do you understand by photo-synthesis ? Describe some experiment by which you can demonstrate the products of this process. C. U. 1917.

2. What external conditions are absolutely indispensable for the formation of starch in leaves. Give reasons for your answer. —C. U. 1932.

3. How would you show by experiment that starch is only formed in leaves when they are exposed to sunlight ?—C. U. 1928, 1914. 1911.

4. What is chlorophyll ? What is its use in plant growth ? Is it invariably present in all plants ? What conditions are necessary for the formation of chlorophyll ? How can you demonstrate the influence of light on the function of chlorophyll ?—C. U. 1931, 1925, 1916.

5. What is assimilation ? Explain the difference between the pea plants and other green plants as regards their nutrition. What is the significance of this difference ?—C. U. 1930, 1921, 1914, 1909.

Hint :—Cultivation of pea or allied plants enriches soil with nitrogen and thus increases its fertility. It also compensates the loss of nitrogen caused by the cultivation of other crops ,

6. What is meant by symbiosis ? Distinguish between parasites and saprophytes. Give examples.—C. U. 1913.

7. How are the feeding processes in plants influenced by the alternation of (a) day and night (b) summer and winter.

Hint :—During day more water and raw food materials are absorbed than those in night hence feeding process increases during day but diminishes at night In winter less water is absorbed than that transpired but in summer absorption increases with the rise of temperature so new organic compounds begin to form in this season.

CHAPTER V

METABOLISM AND RESPIRATION

Metabolism

We have noticed that constructive or synthetic process, taking place in the plant results in the elaboration of protoplasm. There is also the destructive process in which the protoplasm is decomposed and several substances are formed along with the production of heat and energy. A certain amount of protoplasm is lost for the production of heat but the energy set free during the decomposition is mainly used in the process of growth. No plant can live unless both these two processes of construction and destruction or composition and decomposition of protoplasm go on side by side. Constructive processes, such as photo-synthesis, nitrogen assimilation, etc., constitute **anabolism**. Destructive processes, such as respiration, constitute **catabolism**. The sum total of these two processes is called **metabolism**.

Respiration

Like animals, plants respire or breathe. The breathing process consists in inhalation or absorption of oxygen and exhalation or the evolution of carbon dioxide gas. Plants are not provided with special respiratory organs. All parts of plants are concerned with the absorption of oxygen which usually passes through stomata, lenticels, etc. The oxygen is taken up by protoplasm which is thus oxidised and broken up into several simpler substances. One of these is carbon dioxide which is liberated by the plants.

While anabolism or constructive process is mainly concerned in the storing up of energy in potential form, the catabolism or respiration converts that energy into kinetic or free form. **Respiration is thus the transformation of the potential energy of complex organic substances into kinetic energy which is expended in growth** or **in other ways**. Without the presence of this kinetic energy no plant can sustain its life, because it maintains necessary heat within the tissues, regulates growth and controls various kinds of movements exhibited by plants. Thus, respiration is as important a process as assimilation. Both of them again are interdependent. One can not take place without the other. Thus, assimilation can not go on if there be no respiration. Conversely, respiration is impossible if there is no elaboration or construction.

Carbon assimilation and respiration compared

Carbon Assimilation	Respiration
(1) It is a feeding process (anabolism).	(1) It is a breathing process (catabolism).
(2) It consists in the absorption of CO_2 and evolution of O_2.	(2) It consists in the absorption of O_2 and evolution of CO_2.
(3) It occurs only where chloroplasts are present.	(3) It occurs in all parts of plants, green or non-green.
(4) It occurs when sunlight is present and stomata are open.	(4) It occurs both day and night, independent of light.
(5) It causes gain in weight of plants due to construction.	(5) It causes loss in weight of plants due to destruction.
(6) Air gains more oxygen.	(6) Air gains more carbon dioxide.

To prove that plants breathe

Expt. 1. If plants be deprived of oxygen they become sickly and at last die as their respiration is checked. This is often noticed in pot plants which are planted too deeply or covered with too much earth.

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Their roots can not get the required oxygen for breathing. On the other hand, growth is not affected if the upper crust of soil is loosened so as to allow free access of air to the roots.

Expt. 2. If two closed bottles of equal size are taken and if one of them is half filled with germinating seeds while the other is empty, it is noticed after a day by plunging a burning taper in the two bottles that, the taper in the bottle containing the seeds goes out at once and that in the other bottle goes out after burning for a time. The taper going out at once shows that the bottle does no longer contain oxygen which has been replaced by carbon dioxide as the result of respiration. The other bottle contains oxygen which supports combustion. This proves that oxygen is absorbed and carbon dioxide is evolved when plants breathe.

Expt. 3. Four corked glass bottles are arranged in one line on a table. The corks are perforated with two holes for passing tubes. The bottles are connected by the bent tubes as shown in the figure. The bottle A contains strong caustic potash solution, B contains lime

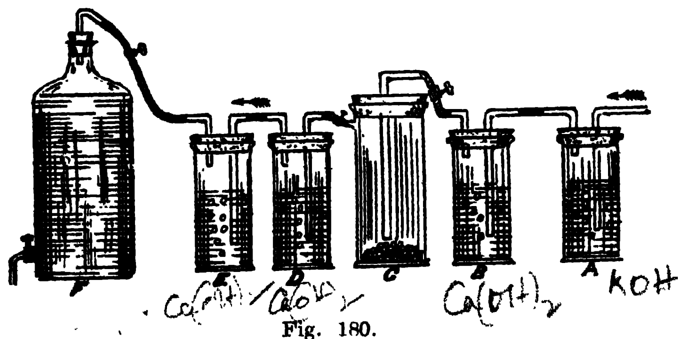


Fig. 180.

Apparatus to prove that plants respire. A—With potash solution. B, D, E—With lime water. C—With germination seeds. F—Aspirator.

water, C. germinating seeds of gram and D. lime water. E, containing lime water, is connected with an aspirator full of water in such a way that when water is allowed to fall, air is sucked in into the aspirator through A and other bottles. Thus so long as the water flows out there is a current of air passing through all the bottles. When air enters A, the carbon dioxide of it is absorbed by the potash

solution. When the air enters B, it is freed from carbon dioxide and so the lime water in B is not turned milky. The air now consisting of oxygen and nitrogen only enters C where respiration is going on. When the air enters D, the lime water there is turned milky which shows that the air now contains carbon dioxide derived from C as the result of respiration. The lime water in E remains unchanged if the air is now quite free from carbon dioxide. This proves that carbon dioxide is given out during respiration.

Parts which respire vigorously

Though respiration occurs in all parts of plants, vigorous respiration takes place in the following parts :—

(1) Germinating seeds, (2) developing buds of flowers and leaves, (3) rapidly growing parts and (4) living and active cells.

Effect of respiration of plants on animals

In the daytime both respiration and carbon assimilation go on simultaneously. It is known that CO_2 exhaled in respiration is poisonous to animals. The injurious effect of the evolved CO_2 is counteracted by the process of carbon assimilation ; and again CO_2 given off by animals during their respiration is also utilised by plants in photosynthesis.

At night, when there is no carbon assimilation and when plants only respire, the atmosphere, under trees, becomes vitiated with CO_2 continuously evolved. Animals, remaining under trees, go on adding to the atmosphere fresh volumes of CO_2 which being heavy settles down. It is, therefore, unwholesome for any man to sleep under trees at night.

Respiratory Quotient

There is a relation between the volume of oxygen absorbed and the volume of carbon dioxide given off.

This relation is not always constant. The relation may be indicated by the fraction $\frac{\text{volume of } CO_2}{\text{volume of } O_2}$ which is called **respiratory quotient**. When this is equal to 1, the volume of oxygen is equal to the volume of carbon dioxide.

The quotient is slightly less than 1 in oily seeds. In succulent plants, it is less than even ·5, as there is abundant organic acid formed in their cell-sap due to the storage of carbon dioxide.

To prove that the respiratory quotient is nearly one or the volume of oxygen absorbed is nearly equal to the volume of carbon dioxide given out.

Expt. Placing a number of flower buds in a flask and pushing a plug of cotton wool in the lower part of the neck of the flask it is inverted over a trough of mercury If it be kept in this position for a day no change in the level of mercury is noticed. This is because the volume of oxygen in the flask used up by the flower buds is nearly equal to the volume of carbon dioxide exhaled. Now by means of a bent tube a little caustic potash solution is introduced into the flask when the solution floats on the mercury, Within a short time it will be noticed that the mercury goes on rising in the flask till it fills up one-fifth of the whole volume of the flask due

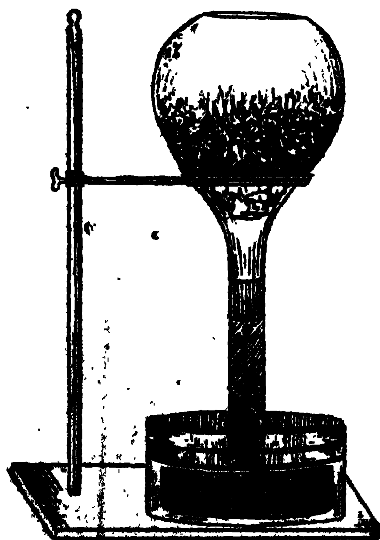


Fig. 181.
Respiration experiment.

to the absorption of CO_2 which has replaced the oxygen forming one-fifth of the volume of air.

To prove that heat is evolved during respiration

Expt. Two bottles half filled with caustic potash solution are placed in a large glass vessel. The mouth of each bottle is covered by

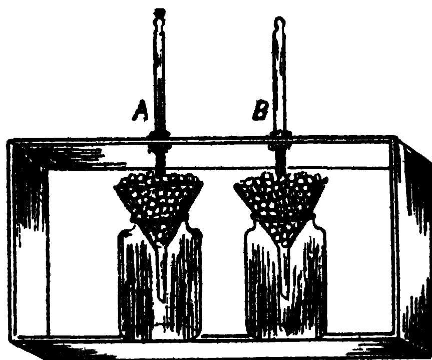


Fig. 182.

To prove the generation of heat during respiration.

a funnel. One funnel is filled with germinating seeds while the other is filled with boiled seeds. A thermometer is inserted into the seeds in each funnel. It is noticed after a time that the thermometer in the germinating seeds indicates rise of temperature while no such rise is noted in the other thermometer.

Intramolecular respiration

The respiration with the absorption of oxygen as seen in ordinary green plants is called **aerobic respiration.** In germinating seeds, respiration may take place to a certain extent, even if they are deprived of oxygen. The oxygen required during respiration is not taken from outside but is supplied from within as the result of the decomposition

of complex compounds when they come in contact with various chemical bodies called enzymes and produce many plastic bodies and liberate carbon dioxide. This kind of respiration is called **anaerobic or intramolecular respiration.**

To prove intramolecular respiration

Expt. After removing the seed coats of several germinating seeds of *chhola* they are carefully introduced into a test-tube which is already filled with mercury and inverted over a dish of mercury. The seeds rise in the tube and rest at the top displacing their own volume of mercury.

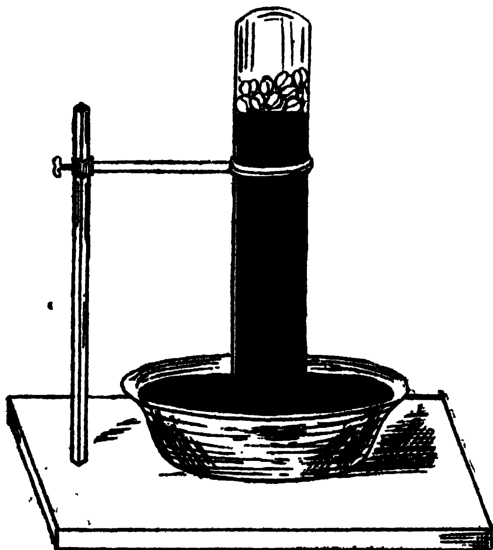


Fig. 183.

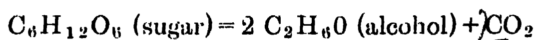
To prove intramolecular respiration with germinating gram seeds.

Within a few hours it is noticed that the level of mercury sinks due to the formation of a gas. A little potash solution is passed into

the tube so that it floats. Soon the level rises owing to the absorption of the gas by caustic potash solution. This gas is oviously CO_2 and has been given out by the seeds, though there is no absorption of O_2 from outside.

Fermentation : Putrefaction.

Fermentation is a chemical process similar to that of intramolecular respiration in which various organic substances are decomposed by many Fungi and Bacteria without the supply of oxygen. The energy is obtained in a way differing much from what is noticed in a typical oxygen respiration. The decomposition is usually effected by the help of ferments secreted by the living protoplasm. They can be extracted and can act apart from the protoplasm which can also act itself as a ferment. In Yeast, the ferment, known as **zymase,** when extracted, can be induced to set up alcoholic fermentation in sugar solution according to the equation--



$$C_6H_{12}O_6 \text{ (sugar)} = 2\ C_2H_6O \text{ (alcohol)} + 2CO_2$$

When complex nitrogenous substances are acted upon by Bacteria producing obnoxious gases along with CO_2, such fermentation is known as **putrefaction**.

In soil, dead organic substances are usually decomposed in this way to render them available for absorption by higher plants. The process of converting these organic substances into soluble nitrates after successive chemical changes, is called **nitrification.** (See page 282).

Products of metabolism

(1) **Plastic substances.**—They are, at sometime or other, made use of by the protoplasm as food materials. They may be formed both anabolically or katabolically.

Those formed as the results of assimilation are sugars, amides and proteids. While those formed after respiration are starch, cellulose, aleurone grains, oils, inulin, etc.

(2) **Secretions.**—They are indirectly useful to the plants. They may be ferments or enzymes, various pigments such as chlorophyll, carotin, etc., organic acids, as oxalic, citric etc. and aromatic substances.

(3) **Excretions.**—They are not of any use to plants. They are alkaloids like quinine, nicotine etc., resins, gums, tannin and gaseous products, such as carbon dioxide, oxygen, water vapour, etc.

(4) **Energy.**—This comes both from heat and light. We know that during assimilation, the energy stored in the potential form is converted into the kinetic one during respiration. This free energy is used mostly in the building up of protoplasm.

(5) **Heat.**—Dissipation of energy takes place in the shape of heat which is noticed during germination of seeds, unfolding of buds etc.

Removal of waste products

Waste products may be secretory or excretory. As plants have no special excretory organs, they adopt different ways to get rid of their waste products.

The following are the ways :—

(1) Falling of leaves and floral parts.
(2) Scaling of bark.
(3) Production of sugary solution as in flowers.

(4) Excretion of resins, volatile oils, etc., through their special ducts.

(5) Deposition of mineral matters, chiefly carbonates and oxalates of calcium in special cells in the form of crystals.

(6) Presence of acids, colouring matters dissolved in the cell-sap.

(7) Throwing out of water in transpiration, carbon dioxide in respiration and oxygen in photo-synthesis.

Enzymes or Ferments

They are the secretions formed katabolically from protoplasm. They convert the insoluble reserve food into soluble forms when they are transferred. Though they induce the conversion, they themselves are not affected. They are :—

(1) **Diastase**—converting starch into malt-sugar.

(2) **Invertase**—converting cane sugar into grape-sugar.

(3) **Maltase**—converting malt-sugar into grape-sugar.

(4) **Cytase**—acting on cellulose.

(5) **Inulase**—acting on inulin to convert it into fruit-sugar.

(6) **Proteolytic ferments**—converting proteids into soluble peptones.

(7) **Lipase**—converting fats and oils into glycerine which is turned into sugar.

Storage of the plastic substances.

Most of the plastic substances are stored up as food matters in different plant members to be utilised when growth takes place in some parts of plants or when any new organ is to be developed. The insoluble forms of these

materials are starch, fats, oils, proteids, etc., while sugars, amides etc. remain in solution in the cell-sap.

The reserve matters occur in the following members :—

(a) Succulent leaves of *pathar-kuchi*, *ghrita-kumari*, etc.

(b) Roots of biennials as *mula*, *gajar*, *shalgom*, etc., or tuberous roots as *ranga alu*, *shatamuli*, *etc*.

(c) Underground stems as of *alu*, *ada*, *halud*, *ol*, *peyaj*, *mankochu*, *etc*.

(d) Pith, pericycle or cortex of ordinary stems or roots.

(e) Seeds.

Summary of Chapter V.

1. **Metabolism** includes both anabolism or the constructive process and catabolism or the destructive process of plants.

2. **Respiration** consists in the absorption of O_2 and the evolution of CO_2. It is the transformation of potential energy of carbohydrates into kinetic energy which is expended in growth and in other ways.

3. Respiring organs—(1) Germinating seeds, (2) Buds of flowers and leaves, (3) Growing parts, (4) Living cells.

4. Respiratory quotient is the relation of the vol. of CO_2 evolved to the vol. of O_2 absorbed.

5. **Intramolecular respiration** is respiration when it takes place without the absorption of O_2.

6. Products of metabolism—(1)—Plastic substances (2) Secretions (3) Excretions. (4) Energy (5) Heat.

7. Waste products may be removed by (1) falling of leaves and bark. (2) producing nectar, resin. oils, mineral crystals, acids, colouring matters, etc. (4) giving off water, O, CO_2.

8. Enzymes—(1) Diastase (2) Invertase (3) Maltase, (4) Cytase. (6) Inulase. (6) Proteolytic ferments. (7) Lipase.

Exercise V

1. What is respiration ? Describe the process. How would you show experimentally that plants breathe ? By what parts does a plant respire ?—C. U. 1933, 1931, 1926. 1924, 1918, 1915. 1913, 1911.

1. Distinguish between assimilation and respiration. Why is it unwholesome to keep plants in a room where we sleep.—C. U. 1913, 1911.

3. Describe the process of exchange of gases between a green plant and the atmosphere in which it grows. Explain the nature of the mutual gain.—C. U. 1927.

Hint.—The process is assimilation or respiration. Regarding the gain, plants gain by assimilation in building up its body ; by respiration they gain energy. The atmosphere has no gain except getting oxygen.

4. What is intra-molecular respiration ? Describe some experiment to prove the behaviour of plants when deprived of oxygen.—C. U 1920, 1915.

5. Write a short note on metabolism. What are plant enzymes ? How do they act ?—C. U. 1923, 1915.

6. What are waste products ? How does a plant get rid of them.—C. U. 1926, 1916.

7. In what different organs may plants store up supplies of food for future use ? When and in what ways, are these stores used up ? Enumerate the important reserve materials met with in the plants.—C. U, 1925, 1923, 1920, 1917, 1912. 1911.

8. Describe briefly the processes by which plants affect the humidity and composition of the air.—C. U. 1930.

Hint.—The process affecting humidity is transpiration while the processes affecting the composition of air are photo-synthesis and respiration.

CHAPTER VI

GROWTH AND MOVEMENTS OF PLANTS

Growth.

Growth may be defined as the permanent increase of bulk accompanied by permanent change of form. It is usually associated with the formation of new substances. As anabolism is greatly in excess of catabolism, the considerable increase in the amount of plant substance as well as the accumulation of potential energy are much greater than the loss of substance and the expenditure of energy in growing plants.

Conditions necessary for growth.

(1) Supply of **nutritive materials**. (2) Proper supply of **water** which is not only the medium for carrying nutritive materials but also maintains the turgidity of growing cells. (3) **Oxygen** which is required for the oxidation of protoplasm with the production of energy. No growth can take place without energy. (4) Suitable **temperature**. Maximum temperature is that above which plants can not grow, and minimum temperature is that below which growth can not take place. Between these two temperatures there is an optimum temperature at which plants grow best. (5) **Light** of moderate intensity, as strong light

affects growth. (6) Supply of **carbon dioxide** so that anabolic process may be more vigorous than catabolism. (7) The cells of the growing members are **meristematic** i. e. in a constant state of division.

Phases of growth.

A growing organ has to pass through three phases successively :—

(1) **Embryonic phase** in which there is rapid division of cells giving rise to new cells. Protoplasm fills up the whole cavity of the cells which are very turgid. The vacuoles are not formed.

(2) **Phase of elongation** in which the new cells formed become greatly elongated. The protoplasm in these cells is in a lining layer containing vacuoles.

(3) **Phase of differentiation** in which the cells, having attained the maximum increase in size, gradually become differentiated or adapted for the work they are to perform.

We see that throughout the growing region the growth is not uniform. It begins slowly just at the tips, increases to a maximum a little behind the apex and then becomes gradually slower till it stops altogether. This is well-seen in the stems of sugar-cane, bamboo, etc., where the internodes at the base are much crowded ; above them the internodes are much elongated but those at the apex again are short. The time taken by any growing organ or cell to pass through these varying rates of growth is called **grand period of growth.**

To determine which region of a growing root grows fastest.

Expt. In a corked jar containing some water and lined with blotting paper a germinating pea seed with a well-developed radicle is fixed to the cork by means of a pin. Make a series of marks with ink on the radicle in transverse lines one-twelfth inch apart by means of a sharp pen-nib. It is found after a day or two that the first few of the upper lines at the tip remain unchanged. But below these the lines are widely separated from each other. Below them again the lines are not so separated. The lower lines remain as far apart as before. Thus the region of the greatest elongation is located. The rate of growth slows down beneath that region till it stops.

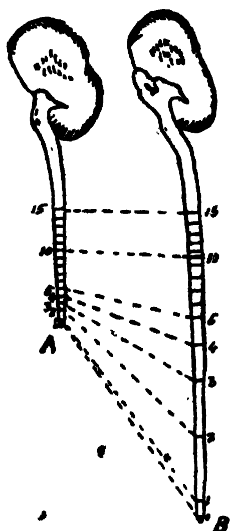


Fig. 184.
To determine the longest region of growth of a radicle. A—Before experiment. B—After experiment. The corresponding marks are shown in A, B.

To measure the rate of growth in length of plants by auxanometer

Expt. The **auxanometer** consists of a smoked drum which is rotated by means of a clock-work arrangement. There are two wheels, one of which is larger than the other, arranged concentrically and kept in position on a vertical stand as shown in the figure. A string passes over the small wheel, one end of it is attached to the apex of a growing plant and the other is connected with a weight. As the plant grows in length the weight descends. Over the large wheel passes another

string, two ends of which carry equal weights. A pointer attached to one of these weights touches the drum. The distance through which

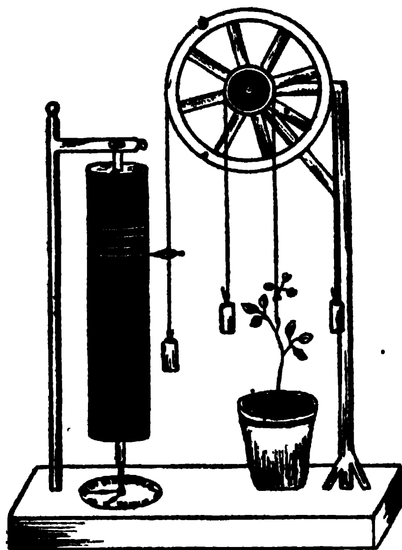


Fig. 185.

Auxanometer for measuring the rate of growth in length of plants.

the weight descends in a given time as shown by the pointer on the drum indicates the rate of growth.

It is noticed that growth increases at night but diminishes during the day. The maximum growth takes place in the morning while minimum growth is found in the evening. Thus, the growth varies during the whole of day and night. This variation of growth during every twenty-four hours is called **daily period of growth in length**.

Growth movement of nutation.

Growth is not always equal on all sides round the growing point. It is very rapid first on one side and then on the other. Thus, the growing point does not elongate in a straight line. Moving from side to side in a zig-zag course, it describes a spiral. This sort of nodding movement is called **nutation**. In tendrils, instead of being alternately on one side and then on the opposite, the region of elongation passes gradually round the growing zone in a circle. This sort of nutation is called **circumnutation**.

Hyponasty and epinasty.

These two kinds of movements are found to occur in the leaves and floral members. In a dorsiventral leaf. when it is in the early stage of its growth, the two sides differ in their degree of turgidity and hence the lower side grows faster than the upper one. This condition of growth known as **hyponasty** is found in the folding up of leaf-buds. Similarly, in fern-leaves where ptyxis is circinate, the upper surface is concealed as the leaf-bud is in the form of a dog's tail. Later on, when the leaves grow older and gradually unfold, the upper surface grows more rapidly as the maximum growth then changes to the upper side. This condition of growth is **epinasty**.

Irritability.

When the movement occurs in plants due to internal causes it is spontaneous. The protoplasmic movement of rotation and circulation (page 183) is the example of spontaneous movement exhibited in plants. But when

the movement takes place in plants due to the influence of external stimuli it is called **induced movement** or **irritability** (See page 103). **Irritability is one of the properties of protoplasm by which protoplasm, when stimulated from without, has the power of receiving impression or giving response to some external stimulus.** The stimuli which induce movements in plants by their action on protoplasm are (1) **Light**, (2) **Gravity**, (3) **Moisture**, (4) **Temperature**, (5) **Chemical substance**, (6) **Contact**.

Light.

When the reactions between the plant and its surroundings are properly adjusted, protoplasm is healthy in its condition. The proper adjustment of light affecting the plant is **phototonus**.

The influence of light affecting plants may be **paratonic** or **heliotropic**.

The paratonic influence of light is well-seen when it acts on the chloroplasts in the palisade parenchyma of dorsiventral leaves which are stimulated by variation in the intensity of light. In diffused light, the chloroplasts of the palisade cells are arranged on their upper and lower walls. The leaves are placed flat or horizontal so that their broad surface is presented to the incident rays of the sun. This sort of arrangement of chloroplasts is called **apostrophe**. When the sunlight is very strong, as at the mid-day in summer, the chloroplasts of the palisade cells are all collected on their lateral walls, so they are protected from being decomposed. At this time the vertical position of leaves is an adaptation for protecting the

chloroplasts from the scorching heat of the sun. This arrangement of chloroplasts is known as **epistrophe.**

Alternation in the intensity of light to which the plant is freely exposed, exercises an influence on the behaviour of its leaves which assume different positions during the day and night. Towards the end of the day, when the intensity of light is diminished, leaves of many plants or the leaflets of compound leaves droop or turn



Fig. 186.

Leaves of *atushi* showing sleep-movement. A—Normal position of leaves. B—Drooping position

their ends upwards or downwards in such a way that their position is nearly parallel to the stem or leaf-stalk. Leaflets of many leguminous plants, *amrul* and other leaves as well as cotyledons show this peculiar movement. This is chiefly meant for protecting the leaves from excessive transpiration and loss of heat. This movement showing

the changes of leaf-position in response to the stimulus of alternation of light and darkness in called **nyctinastic** or **sleep-movement**. It is due to the change in the turgidity of the parenchymatous cells of the pulvinus. The cells of the pulvinus absorb water on one side and swell, while those on the other lose water and collapse Thus the pulvinus along with its upper portion i. e. the whole leaf droops.

Tropisms.

1. **Heliotropism is the property which enables the plant-organs to take up definite positions in relation to light**. The stimulus of light has an action on the direction of growth. Different parts of plants react in different ways and thus curve when exposed to light. It is a common observation that during the germination of any seed, the radicle, soon after its release from the seed-coat, turns away from light and grows downwards towards the soil where there is total absence of light. This takes place in whatever position the seed is placed—upwards, sideways or downwards. · On the other hand, the plumule begins to grow erect as it seeks light. It is for this reason that the stems are **positively heliotropic** and roots are **negetively heliotropic**. Leaves are called **dia-heliotropic** or **transversely heliotropic** as they place their surface at right angles to the incident rays of light.



Fig. 187.
Heliotropic experiment

To prove that shoots are sensitive to ligh

Expt. A plant is grown in a dark room with only a small windo on one side kept open. Within a few days it is noticed that the erec stem bends at its apex towards the window in order to catch light The leaves arrange themselves at right angles to the stem.

2. **Geotropism is another property which makes the plant-organs sensitive due to the stimulating influence of gravity.** Under the action of this stimulus the primary roots grow vertically downwards into the soil and the stem vertically upwards into the air. Thus, roots are **positively geotropic** and stems **negatively geotropic**. Rhizomes, stolons grow at right angles to the direction of gravity, so they are diageotropic.

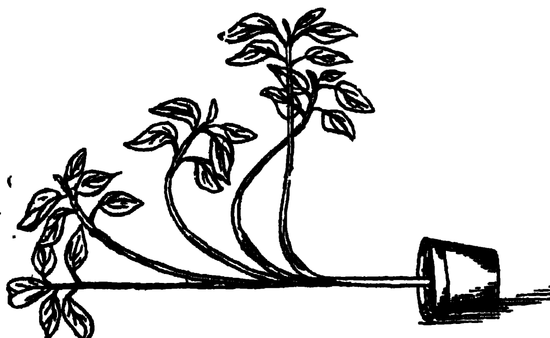


Fig. 188.
To prove geotropic curvature of a shoot.

Expt. 1. A branched pot plant is placed horizontally and is allowed to grow in that state. Within a few days the branches are found to turn upwards and continue to grow vertically. The leaves place themselves at right angles to the branches. These successive curvatures of the branches show their geotropic movements.

Expt. 2. Fixing several seedlings on a wheel mounted on a **vertical** axis and revolving the wheel rapidly it is noticed that though the seedlings are all the time under the action of gravity they are influenced by the greater centrifugal force of the wheel. So the roots instead of growing vertically downwards grow away from the centre of

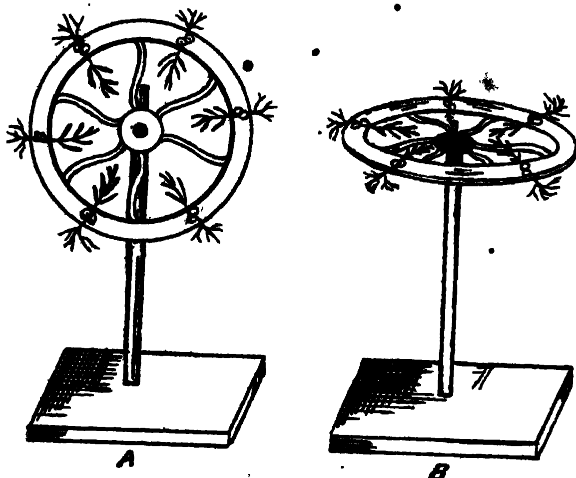


Fig. 189.
Knight's wheel experiment.

wheel while the stems grow towards it. If the axis of the wheel be **horizontal** and the seedlings are kept horizontally on the wheel, no curvature is noticed as all the parts of the seedlings are affected equally. This is known as knight's wheel experiment.

3. The response made by the growing organs to the stimulating influence of moisture as regards their direction of growth, is called **hydrotropism**. Roots, moving towards water in the soil, are positively **hydrotropic**.

Other stimuli.

(1) **Chemical stimulus.**—The tentacles on the leaves of sun-dew, the spermatozoids of Pteridophytes, attracted by malic acid or sugar, show **chemotactic** movements.

(2) **Heat** also exerts an influence on plant-organs which exhibit **thermotropic** movements.

(3) **Contact** acts as a stimulus to many growing organs as tendrils, root-tips etc. We have noticed that the trap door of bladder-wort is sensitive to the minute water-insects. All of us know that as soon as a leaf of *lajjabati* is handled, suddenly the leaflets droop downwards. All the leaves of the plant behave in the same way if the handling be rough.



Fig. 190.
Lajjabati leaves.

Summary of Chapter VI.

1. **Growth** is the permanent increase of bulk accompanied by the permanent change of form.

2. Conditions of growth—(1) Food (2) Water (3) Oxygen (4) Temperature (5) Light (6) Carbon dioxide (7) Meristematic cells.

3. Phases of growth—(1) Embryonic phase (2) Phase of elongation (3) Phase of differentiation.

The time taken by a growing organ or cell to pass through the varying rates of growth is called the **grand period of growth.**

4. **Nutation**—When the movement is in a zig-zag cours it is nutation but it is circumnutation when the movement describes a circle. When the lower side of a leaf grows faster than the upper one, the condition of growth is **hyponasty** but it is **epinasty** when the upper side grows faster.

5. **Irritability** is the sensitiveness of protoplasm which when stimulated under the influence of external stimuli has the power of responding to them.

6. Light—The inflence of light may be **heliotropic** or **paratonic**. **Apostrope** and **epistrope** are different movements of chloroplasts in the leaves exposed to the varying intensity of light while sleep-movements of leaves at the end of the day by their foldings are the examples of paratonic influence of light. **Heliotropism** enables the plant-organs to take up definite positions in relation to light.

7. **Geotropism** makes the plant-organs sensitive due to the stimulating influence of gravity.

8. **Hydrotropism** makes the organs sensitive to take up definite position in relation to moisture. Other stimuli are chemical substances, heat and contact.

Exercise VI

1. What external conditions influence growth of plants and what are the effects produced by them. Give examples. What is growth ?—C. U. 1925, 1922, 1919, 1913.

2. How would you determine experimentally which part of a young seedling is growing the fastest ?—1929, 1912.

3. What is meant by irritability in plants ? What manifestation of it occurs in nature ? Of what use is it to the plant.—C. U. 1914.

4. Write short notes on heliotropism and geotropism. Describe simple experiments of demonstrate geotropism and heliotropism in plants.—C. U, 1928. 1926, 1915.

5. Give instances of sensitiveness of plants to contact.—C. U. 1911.

CHAPTER VII

REPRODUCTION.

Kinds.

All plants, high or low, must reproduce themselves in order to propagate their species. Before they die, they leave apart structures by which the spreading of the species is possible. The structures so separated may consist of a single cell or a group of cells. There are three ways by which reproduction is effected :—(1) **Vegetative**, (2) **Asexual**, (3) **Sexual**.

Vegetative reproduction : its occurrence.

This simple process of reproduction consists in the **separation from the plant of any vegetative part which becomes more or less specialised for the purpose of multiplication**. The part is produced directly from ordinary vegetative organs and when detached is capable of giving rise to a **new individual quite similar to the mother plant**.

In higher plants, the following are the organs by means of which vegetative reproduction can take place :—

(1) **Radical buds**, produced from roots under special circumstances as in *patole*. (See Buds, Morphology)

(2) **Epiphyllous buds** as in *patharkuchi* leaves.

(3) Modified buds called **bulbils** developed at the axils of leaves of *chupri alu*, etc.

(4) **Gemmae** formed on *liverworts*, *moss*, etc.

(5) **Adventitious buds** developed on the upper surface of the leaf-lamina of ferns as in *walking ferns*.

(6) Aerial modifications of stems become highly specialised to serve chiefly the purpose of vegetative propagation. They are **runners**, **off-sets** and **suckers** (see pages 59—60).

(7) The underground types of stems as **rhizomes, tubers, corms** and **bulbs,** fully adapted for multiplying the species vegetatively, produce buds to give rise to new shoots (see pages 52—54).

(8) **Cuttings** of many stems and roots placed in the soil give rise to new individuals under favourable conditions. Examples can be found in *jaba*, *jeoli*, *ak*, etc.

(9) **Grafting**, or causing a shoot of one plant to adhere and grow on the body of another, is also a way for propagating special varieties.

In lower plants, new individuals are formed vegetatively by ordinary cell-division, as in *spirogyra* or by means of budding, as in *yeast*. In Bacteria, mere splitting of walls causes the formation of new organisms.

Asexual reproduction.

This consists in the formation of a highly specialised single reproductive cell or **spore** which gives rise to a new organism. This differs from the vegetative method in this that the specialised body is unicellular in asexual reproduction while the body is multicellular in the vegetative method. The new organism formed always resembles the mother plant in the vegetative method but in the asexual method it may or may not resemble the parent.

In the flowering plants there are two different types of asexual spores formed on the plant which is known as a **sporophyte.** Pollen grains and embryo-sac of the ovules are the two different spores formed on the flowering plant. The plants are called **heterosporous** owing to their formation of two types of spores. In Pteridophytes, the plants may be **homosporous** or heterosporous according as the spores formed on them are of one type or two. Asexual spores are usually developed within a case called spore-sac or **sporangium.** In higher plants, the leaves, bearing or protecting the spores, are called **sporophylls.**

Sexual reproduction.

This consists in the formation of two kinds of highly specialised cells for the purpose of reproduction. These cells are singly incapable of producing any new organism but they fuse together to be capable of producing a new individual. These cells formed are called sexual cells or **gametes**. The plant on which they take their origin, develop and fuse together is called **gametophyte**.

When the gametes are indistinguishable into male and female the process of fusion is called **conjugation**. But when the gametes are distinguished as male and female, the process of union is called **fertilisation.** The product of conjugation is **zygospore** while **oospore** is the result of fertilisation. The term **zygote** applies both to zygospore and oospore.

Exercise

1. Write a short essay on vegetative reproduction in plants. Give examples.—C. U. 1928, 1918, 1917, 1912.

PART IV

ECOLOGY

Ecology is that branch of Botany which deals with the relation of plants to their surroundings. It enquires into the physical features of the place where the plants grow. It also investigates the different modifications of the plant-organs in adaptation to those features of the place. As regards the physical conditions we are to consider the duration and intensity of light, the temperature, the character of the soil, elevation, the amount of moisture, wind, etc.

Plant associations.

There is a continuous struggle for existence going on among the plants similar to the struggle noticed among the animals. A plant becomes an unsuccessful competitor and has to perish at last if it fails to adapt itself to the external conditions which are constantly varying owing to the forces of nature and to the actions of animals and human beings. Thus, a plant which has adapted its structure for living entirely submerged in water can not grow in any place out of water, as it must fail in open competition to adapt itself to the atmospheric conditions. It is for this

reason that plants belonging to widely different families are found to be associated together which are capable of adapting their organs to the same dryness and moisture of soil, the same conditions of temperature surrounding the plants, the same amount of light, etc. Such groups of plants growing in the same locality and tending to resemble each other, as far as their leaves, roots and stems are concerned, are called **plant associations.** The power of adaptability lies in the vegetative parts and is not usually seen in the structures of flowers of the associations.

Classification.

From the point of view of ecology, the flowering plants are classified mainly into three groups :—(1) **Hydrophytes** or water plants living entirely in water or in soil containing 80 per cent water, (2) **Xerophytes** or desert-loving plants living on rocks or in soil which is poor in water. The plants growing on sea shore are also xerophitic in their habit as the abundance of salts in the soil decreases absorption so as to prevent loss of water by transpiration. All xerophytes have to struggle much for securing water and holding that in them. They adapt their structures accordingly. (3) **Mesophytes** are intermediate between the two.

WATER-PLANTS :—THEIR CHARACTERISTICS

The conditions of life of these plants in water are more uniform than those to which a land-plant is exposed. As water gets hot and loses its heat less quickly than land, the water-plants are not to suffer from sudden changes of

temperature which in most cases affect land-plants. As water contains carbon dioxide more in proportion than air and as oxygen always remains dissolved in water, the processes of assimilation and respiration are more easily carried on. On the whole, the adaptation of their structures is such as to ensure vigorous transpiration in proportion to the absorption. The reduction of absorption is usually effected by the lower temperature of water as compared with that of land.

Roots are usually always adventitious. They are never hard. The whole root-system is feebly developed. In *paniphal*, *topapana*, the roots are fine, thread-like and clustered. In *padma*, *lily*, the roots are not provided with root-hairs. In some cases the root-cap is also absent. In water-plants, as absorption of water and food materials dissolved in water goes on over the whole submerged surface, roots in some cases are totally wanting as in *bladder-wort*. In other cases, the roots are used more as organs of attachment than of absorption. In *keshardam*, cotton-like floating roots are developed from stem-nodes, to make the plant light.

Stems have their woody tissues poorly developed, i.e. they are very soft and without lignification. Their epidermis is not at all cuticularised, so the whole surface is able to absorb water. The internodes are long. As water gives support to the stems, there is reduction or total absence of sclerenchymatous tissue. They are thus soft but so pliable that they can easily be swayed by water current without breaking. They are full of large air spaces called **lacunae** which facilitate the passage of oxygen required for respiration, and maintain the buoyancy of the plants. The central arrangement of xylem in the stems is also sufficient

to meet the slight pulling strain of water. They are never erect but usually much reduced. In most cases they are of underground forms as of *saluk*, *padma* etc. where they are rhizomous or bulbous. In some cases as in *kalmi*, *hinche*, etc. they are runners.

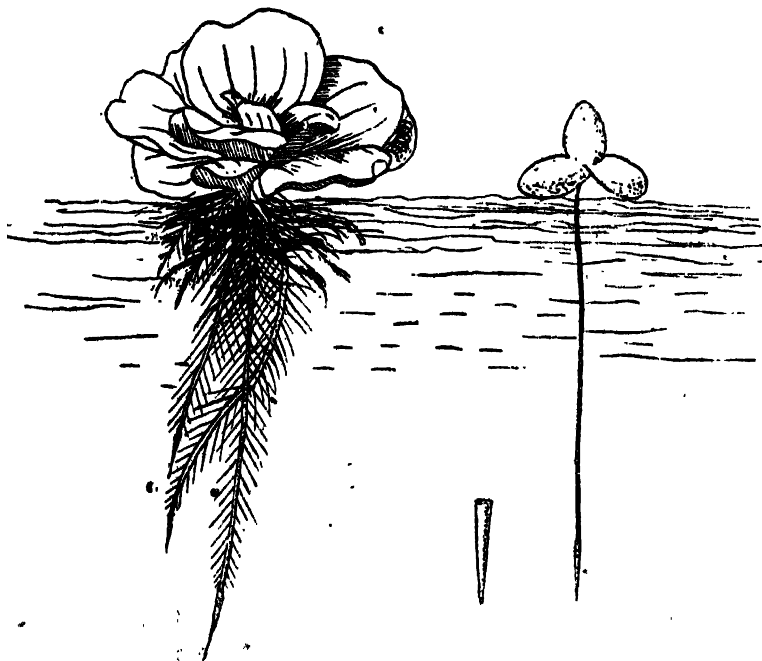


Fig. 191.
Pana.

Leaves may be submerged or floating or both. Those living entirely under water are either long, thin, and ribbon-like as *pata-shaola* or finely divided so that greater surface is offered for the absorption of the

gases dissolved in the water. The fine division is also meant for giving less resistance to the current of water so that the current easily passes without injuring the leaves. Usually, ribbon-like leaves are formed when the plants grow in still water. But the plants living in moving water have dissected leaves. The submerged leaves have no stomata or cuticle as there is no transpiration. In floating leaves, the stomata are on the upper surface. To protect these stomata from being



Fig. 192.
Kachuripana

choked up with water, the upper surface of such leaves are made so smooth by the cuticular or waxy covering that water easily runs off. As the chloroplasts have not to be protected from the strong light, the palisade tissue is totally absent and the chloroplasts are present in the epidermal cells. The floating leaves are more or less round, entire and full of air spaces which are continuous with the air-passages running down the elongated flexible petioles to the stems

and roots as noticed in *padma*, *shaluk* etc. In *kachuri pana*, the petioles are much swollen due to the presence of numerous air cavities which not only enable the plant to float by giving lightness to it but also help in respiration.

Reproduction, in most cases, takes place mainly by the vegetative means. The ease with which the submerged plants are supplied with water, salts dissolved in water, carbon dioxide and oxygen, and the perfection with which the processes of nutrition and respiration are effected, lead to rapid development and growth, and so result in extensive vegetative reproduction. The conditions of life led under water are particularly and peculiarly favourable for growth and propagation. If the older parts of any plant decay, the free branches give rise to new plants independently or if any portion of a plant is broken off and set free, it grows into a new plant as in *pana*, *khude pana*. This is because the branches or the broken portions are not dependent on the production of roots for their food supply. In cold climates, water-plants form special winter-buds at the ends of their stems or branches to protect themselves against frost. These buds containing reserve food drop off and fall to the bottom of the pond where they remain during the winter to grow up in the spring.

Flowers seldom appear from the submerged water-plants. In *patashaola*, a submerged plant, flowers are pollinated by the current of water on the surface of which they rise during pollination. In floating plants, the flowers are usually highly coloured to attract pollinating insects as in *kachuri pana*, *padma*, *shalook*, etc. In some plants,

flowers may be adapted for wind-pollination. The majority of water-plants are perennials.

Xerophytes : their characteristics.

Xerophytes grow in sandy or rocky soils, on high mountainous regions and on sea shore. From these situations plants secure required water with great difficulty. The adaptations of structures of these plants are such that this precious water is not lost from too great transpiration. They have to adapt themselves to economise their lessened supply of water. As, on one hand, there is the reduction of food absorption from the soil due to the abundance of salt or humus in the soil or to the low temperature of soil there is, on the other hand, the tendency of the increase of transpiration as the plants are well exposed to the high winds on sea shore, or on high mountains where the barometric pressure is too low.

The adaptations for increasing their absorption are noticed in the following modifications. (1) The roots are deeply penetrating and much branched. (2) The ramifying root-system is purely meant for gathering as much water as it can. The adaptations to meet extremes of temperature, strong insolation and dryness are noticed in the following characters. (1) The stems are stunted in their growth. (2) They are much lignified and thus hardened. (3) There is the development of cork or bark. (4) The epidermis has a strong or thick cuticle. (5) The woody elements are predominant in the system. The contrivances adapted in leaves to check excessive transpiration have been dealt with (page 301). The storage of water is effected by (1) developing water-storing tissues, (2) presence of latex,

(3) presence of mucilage. The last two have the power of retaining water. The succulent plants, as *phani-mansha* and many Euphorbia, grow in deserts and contain an abundance of mucilage, latex and water-storing cells.

Mesophytes.

They differ from xerophytes in possessing thin and normal leaves adapted for the regular and continuous transpiration during the day in proportion to the absorption of water containing the salts from the soil. As a result of this, food substances are properly distributed in the different parts of plants. Stomata develop on the lower surface of leaves though they may occur on the upper surface. Mesophytes differ from the water-plants in having a well-developed conducting system by which a current of water through the plants is always noticed. The whole root is not used for the purpose of imbibition of food solution. The roots, stems and leaves are well-developed and vary according to their habitats.

Exercise

1. What are the chief characteristics of aquatic plants? In what respects do these plants differ from typical land plants.—C. U. 1932, 1912, 1911.

2. Describe briefly plants growing in (a) moist and (b) dry situations.—C. U. 1916.

Give an account of the modifications of the leaves to be met with in (a) aquatic plants (b) plants living in desert areas (c) insectivorous plants (d) climbing plants.—C. U. 1929.

PART V

LIFE HISTORY

CHAPTER I

CRYPTOGAMS

Cryptogams include three groups of plant-forms which, beginning with the simplest unicellular organism, advance through gradations to complex bodies differentiated into stems, roots and leaves. They are also called **spore-plants** as distinguished from Phanerogams called **seed-plants**. The unicellular spores, separated from the mother plant effect the formation of new Cryptogams while the multicellular seeds are the means of reproduction of Phanerogams. Spores, found also in Phanerogams, are not the immediate cause of the formation of new plants.

The three groups of Cryptogams are, as we know before,

(a) **Thallophytes**, (b) **Bryophytes** and (c) **Pteridophytes**.

THALLOPHYTA

The plants of this group are almost undifferentiated i.e., their body does not usually develop any organ for special work. The vegetative body, exhibiting no segmentation, is a thallus. The Thallophytes, thus, consist of simplest plants. In some cases, the plant-body is a single cell ; in other cases, the thallus consists of a long, branched or unbranched filament, or of a group of cells. The plants are thus known as **cellular cryptogams**.

There are different modes of reproduction adopted by the plants. It may take place by cell-division or by the formation of spores sexually or asexually. When spores bear cilia or whip-like threads by which they move actively in water, they are called **swarm spores** or **zoospores**. They are called **aplanospores** when they are not ciliated. Sometimes, vegetative method is also adopted. The usual sexual method is conjugation. Fertilisation is also found in some cases.

This group is usually divided into two classes : (1) **Algae** *(shaola)* and **Fungi** *(chhata)*.

Difference between Algae and Fungi.

(1) The main distinction lies in the fact that the Algae contain chlorophyll but the Fungi do not.

(2) Owing to the presence of chloroplasts Algae are green but in some Algae other colouring matters mask the chloroplasts according to which the plants are coloured. But Fungi are never green in colour.

(3) With the chlorophyll Algae can make their own food out of the CO_2 absorbed and thereby can live

independently. They are thus known as **autophytes.** On the other hand, the Fungi, having no chlorophyll, fail to manufacture their food which they must obtain either from living animals or plants when they are **parasites,** or from dead organic materials when they are **saprophytes.**

(4) For the manufacturing of food, the Algae require light in which they grow. The dependent Fungi have no need for light ; they may grow both in light as well as in darkness.

(5) The products of carbon assimilation in the Algae are starch, oil (in Vaucheria and Chara), glycogen and other complex carbohydrates. The Fungi cannot make use of CO_2 of the air ; so in them starch, sugar, etc., are absent. They absorb nitrogenous compounds and contain many oil globules.

(6) The cell-walls of the Algae consist of pure cellulose while those of most Fungi do not consist of cellulose but of chitin which stains purple with iodine solution and sulphuric acid.

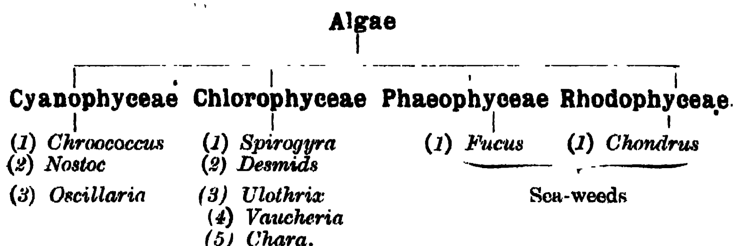
(7) Algae are usually filamentous, consisting of one or several rows of cells attached end to end. They may also be unicellular or consist of groups of cells. The vegetative body of Fungi usually consists of much-branched filaments called **hyphae** which are greatly intertwined to form a web-like mass called **mycelium**. This is composed of one or several **coenocytes**, each containing many nuclei.

(8) Algae are aquatic plants while Fungi usually live on land.

(9) Most of the plant-diseases are caused by the Fungi while the Algae are mostly harmless.

ALGAE

Algae are further classified according to the colouration of the plants. There are four groups of them. They are :—(1) **Cyanophyceae**, when blue green, (2) **Chlorophyceae**, when pure green, (3) **Phaeophyceae**, when olive brown, (4) **Rhodophyceae**, when red. Most of the common plants belong to the first two groups. Plants of other groups are called sea-weeds as they live in sea-water.



ALGAE

Cyanophyceae

(1) **Chroococcus** is a very simple unicellular, blue green alga found to grow in the stagnant water of ponds or lakes. It multiplies by cell-division. The divided cells forming a plate-like mass is totally surrounded by a mucilaginous protective sheath. Sexual reproduction is quite unknown in the plant

(2) **Nostoc** grows in a colony of many filaments invested with a sheath of mucilage. Each filament consists of beaded cells with blue green colouring matter. Reproduction takes place vegetatively by the splitting up of the filaments into fragments called **hormogonia** each of which consists of several cells. At intervals, there are clear spherical cells called **heterocysts** which mark the limits of hormogonia. It is usually found attached to the steps of ponds or to the roots of higher aquatic plants.

(3) **Oscillaria** is another blue green alga occurring in the fresh water of ponds. The body is filamentous consisting of a row of similar cells. Filaments are chiefly characterised by their oscillating movement. There is a sheath of mucilage investing the filament. Reproduction takes place as in Nostoc by the help of hormogonia each of which grows out into a new plant.

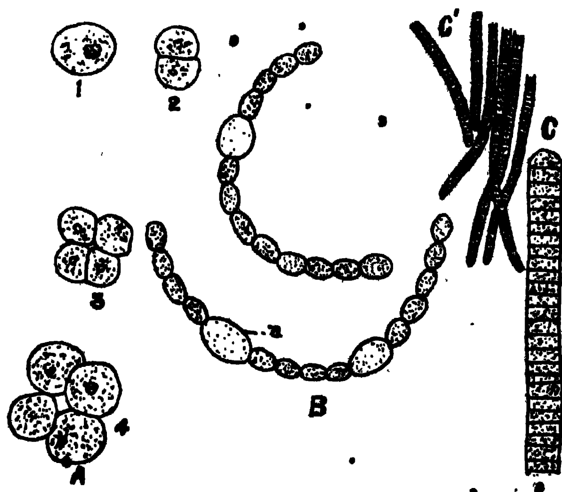


Fig 193.
Plants of Cyanophyceae. A—Chroococcus. 1, 2, 3, 4,—The successive stages of cell-division. B—Nostoc filaments. a—Heterocyst. C—Oscillaria. C′—colony of oscillaria.

ALGAE

Chlorophyceae

A. DESMIDS

Desmids are unicellular algae belonging to Chlorophyceae. They usually occur in the stagnent waters of ponds or lakes. The simple beautiful plants are of many forms viz., rounded, star-shaped, semilu-

nar etc. Whatever be their forms, each is constricted in the middle so that the cell consists of two symmetrical halves. There are two chromatophores with pyrenoids, one in each half of the cell. Nucleus occupies the centre of each plant. Plants show peculiar gliding movement induced by light. In some plants as **closterium**, there is no constriction.

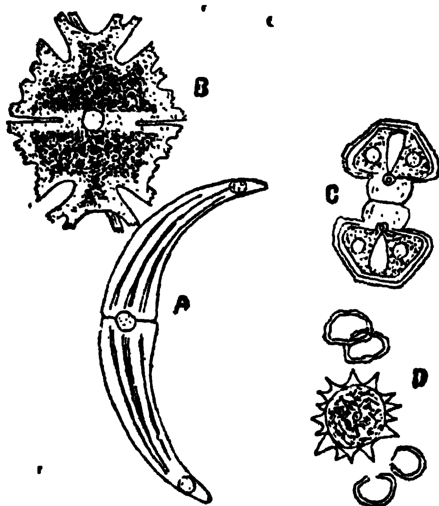


Fig. 194.

Desmids. A—Closterium. B—Starshaped desmid. C—Desmid in the process of cell-division. D—The spinous zypospore in the middle and the vacant cells on the sides.

Reproduction takes place by (1) **cell division** or (2) **conjugation.**

(1) At the time of cell division the central nucleus at first is divided into two along the line of constriction. Protoplasm with the chloroplasts next divides to form two halves, each of which develops a corresponding new half to complete the formation of two entire plants at a time.

(2) **Conjugation.** Two plants approach each other when they become invested by a mucilaginous envelope. Two similar gametes are formed by rejuvenescence and unite when they come out of the cells which rupture at the constriction. The resulting zygospore becomes spinous on its wall and forms after divisions two new plants.

B. SPIROGYRA

General characters

This is a green thread-like plant commonly found in standing water. It grows in a colony which floats freely. The unbranched thread, when magnified, is found to consist of many thin-walled cells attached end to end forming a long row. As the cells are all similar, each can carry on all the vital functions of the plant. So the plant, though morphologically multicellular, is physiologically a colony of unicellular plants as, when the filament breaks up into separate cells, each of these can start a new life and grow independently.

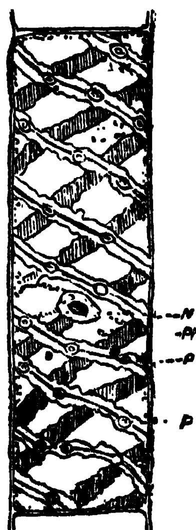


Fig. 195

A magnified cell of a spirogyra filament. N—Nucleus. Pt—Cytoplasmic threads. P—Plastids arranged spirally.

Structure :—Each cell has a slimy wall. Along the wall protoplasm forms a thin layer from which threads traversing the vacuole run to meet in the centre where the nucleus lies suspended. The chloroplasts are

in the form of serrated bands which coil spirally throughout the cell round the vacuole. There are several proteid bodies called **pyrenoids** occurring at intervals in the chloroplasts. The name of the plant is due to this spiral arrangement of the plastids.

Reproduction

(1) **Vegetative method**—Every time a filament is broken off into pieces, each piece, consisting of at least one cell, can grow out into a new filament by ordinary cell-division.

(2) **Conjugation**.—This is the normal mode of reproduction, specially when food materials run short. Two conjugating filaments lie side by side when outgrowths appear from the walls of the opposite cells of the filaments. The outgrowths go on approaching each other and finally they meet to form a passage called **conjugating-tube** after the absorption of the common wall in place of contact. In the mean time, protoplasmic contents of the cells recede from the walls, contract and form globular gametes in them. The gametes of the two corresponding cells now pass through the tube and fuse together to form a **zygospore**. As the gametes are similar in size and behaviour, though one of them sometimes becomes more active than the other, their fusion is known as **conjugation**. The zygospore becomes brown and germinates to give rise directly to a new plant after a long period of rest. On first germinating, the young plant is differentiated into base and apex, for it remains for a time attached by one end which is colourless.

It has been observed, however, that two conjugating filaments may at first be glued together when they put out

processes which push the filaments at a distance in the course of their elongation.

Conjugation may also take place between the cells of the same plant, i. e., monoeciously. This method is also

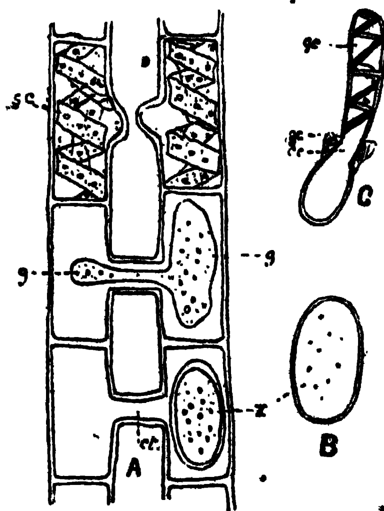


Fig. 196.

A—Two conjugating Spirogyra filaments. g—Gamete. ct—Conjugating tube. z—Zygospore. Sc—Spiral chloroplasts. cc—Colourless cell. oc—Outer coat. Gc—Growing cell. B—Zygospore. C—Germinating zygospore.

known as **chain-like** conjugation as opposed to the **ladder-like** one which occurs between two plants.

(3) **Parthenogenesis.**—Sometimes when conjugation fails to take place, one gamete may directly develop into a resting spore asexually called **azygospore** which can produce a new plant.

C. ULOTHRIX

General characters.—This is another green filamentous fresh water alga preferring to grow in running water. It consists of thin-walled cylindrical cells in one row. Like Spirogyra, it lives in a colony which may float in a green tangled mass. Usually, it is attached to a substratum in the water by a colourless end. The chloroplasts in each cell form a broad band in which the pyrenoids are present.

Reproduction.—The plants multiply by means of both sexual and asexual ciliated spores called **zoospores**. The sexual zoospores are also called **planogametes**. Both the two kinds of zoospores arise from the divisions of ordinary cells of the plant. A zoospore is a naked, pear-shaped body with clear protoplasm at the pointed end. The broader part contains nucleus and chloroplast. There is a vacuole called **pulsating vacuole** which alternately contracts and expands at intervals. At one side of the spore there is one red **eyespot**. At the pointed end there develop two or four cilia by which it moves and swims towards light.

(a) **Asexual.**—The asexual zoospores are bigger in size than the sexual ones. They have four cilia by which they move. When they come to rest they withdraw their cilia and attach themselves by the colourless end to a substratum at the bottom of water. Directly they grow out into new Ulothrix plants.

(b) **Sexual—conjugation.**—When the moving biciliated zoospores coming out from their different mother-cells meet, they at first fuse in pairs at the pointed colourless ends. Gradually, when the conjugation is complete, the

two naked spores become one with four cilia at the end. At this stage, the quadriciliate zygospore formed can be recognised from the single asexual zoospore by their having two eyespots and chlorophyll bodies. When the zygospore is formed, it draws in the cilia, acquires a wall round it and

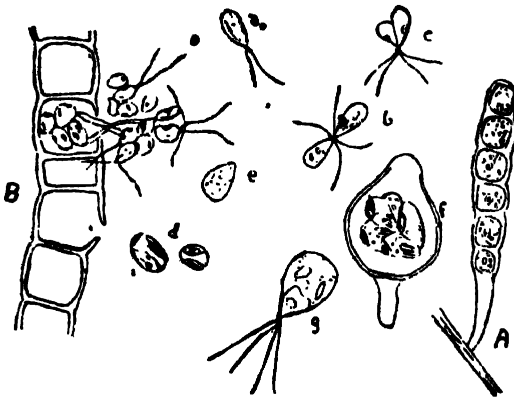


Fig. 197.

Ulothrix. A—Plant attached to the substratum. B—Sexual units coming out of a mother cell. a—Biciliated zoospore. b, c—Conjugating zoospores. d, e—Zygospore. f—Zygospore dividing. g—Quadriciliated zoospore.

takes rest becoming attached to a substratum in the water. The contents now divide into several parts to form asexual zoospore from which new Ulothrix plants are produced directly.

(c) **Parthenogenesis.**—Sometimes, when conjugation fails, any planogamete may act like an asexual zoospore from which a new plant can be produced.

(d) **Vegetative.**—As in Spirogyra, the plant can also multiply vegetatively by the breaking up of the filament into pieces which grow independently.

(e) **Palmella condition** :—When the plant is left stranded by the receding water, the filament forms, after divisions, a colony of round cells each of which is transformed into a thick-walled resting spore. Under favourable conditions of growth, the spore germinates directly or gives rise to a new plant by the formation of a zoospore.

D. VAUCHERIA

General characters.—This is a green alga growing in the fresh water of ponds or in the stagnant water of ditches, specially in the bottom of shallow water. This is also found on damp soil as a green tangled web. The plant is a little differentiated at the place of attachment where colourless root-like processes appear. The plant-body, differing from other plants of the group is a **much-branched filamentous coenocyte.** The branches are formed irregularly or dichotomously. Throughout the plant the continuous protoplasm, with many nuclei and chloroplasts embedded in it, is not partitioned by any cell-wall. Fatty oil is formed in the plant in place of starch as the product of assimilation.

Reproduction :—

(1) **Asexual** :—At the time of reproduction the end of a branch becomes club-like in form in which protoplasm with numerous nuclei accumulates. A partition wall is formed just below the swollen end called **zoosporangium**, thus separating it from the rest of the filament. The whole

contents of the sporangium now contract and become converted into a large green **zoospore** which is ciliated all over. A pair of cilia is opposite to each nucleus lying near the outside in a clear zone of protoplasm. When the

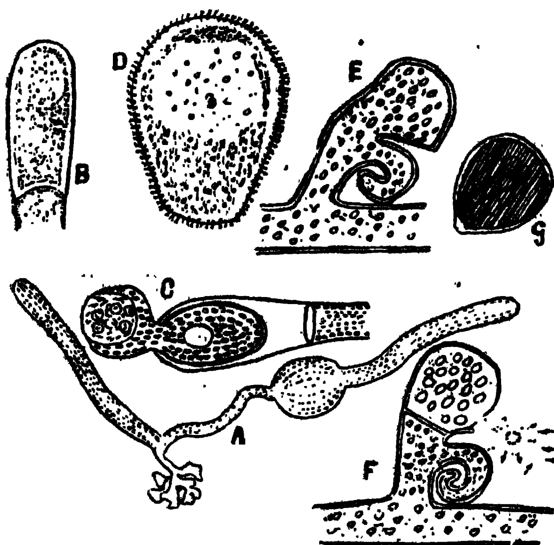


Fig. 198.

Vancheria. A—The plant with the colourless root process. B—Partition wall formed at the end of one filament. C—Zoospore coming out of the mother-cell with difficulty. D—Large, multiciliated moving zoospore. E—A portion of the filament with the terminal oogonium and a curved antheridium. F—Biciliate antherozoids trying to enter the mature oogonium. G—The resulting oospore.

sporangium opens at the apex, the large spore forces its way through it. It then moves lazily for a time and comes to rest after withdrawing the numerous cilia. On germination, it gives rise to a new Vaucheria plant.

(2) **Sexual—by fertilisation**—The plant shows typical **oogamy** as the different sexual cells are formed within differentiated male organs called **antheridia** and female organs called **oogonia**. Spirogyra and Ulothrix are **isogamous** as the sexual cells they produce are of one type while this plant is **oogamous**.

Both the organs arise in close proximity to each other on special branches separated from the rest of the plant by means of septa. The antheridium grows as a short curved branch. The oogonium is terminal and round in form. The antheridium produces many biciliate male sexual cells called **antherozoids** which escape, when mature, by the rupture of the antheridium at its end. The oogonium containing a single **ovum** also opens, when mature, at one side where a beak is formed. An antherozoid now enters an oogonium situated at a distance and fertilises the ovum which then produces an **oospore**. The oospore germinates in due course and directly gives rise to a new plant.

E. CHARA

General characters :—Chara is a highly organised green thallophyte which grows abundantly in the stagnant waters of ponds, jhils and shallow rivers. The cylindrical stem is fixed to the bottom by means of colourless rhizoids. The jointed stem shows a regular succession of nodes and internodes, the nodes sending out whorls of lateral members. The members of limited growth are usually called leaves, while the other members, called branches, repeat the same jointed and branching habit. The stem and its branches become brittle owing to the deposition of lime on the outer walls.

Stem structure :—An internode consists of one long cell covered by a single layer of cortex. The nucleus of the long cell breaks up into many large nuclei by fragmentation. A node consists

of two central cells and a circle of peripheral cells of different ages. The lateral members arise as outgrowths of the nodes. Both the stems as well as the members grow in length by an apical cell.

Reproduction :—The sexual organs, antheridia and oogonia are peculiarly complex, being entirely unlike those of other Algae. They are the outgrowths of the leaves, appearing always in pairs. Each antheridium called **globule** has its wall composed of eight cells called **shields** to each of which an elongated cell called **manubrium** is attached in the middle towards the cavity. Each manubrium bears one head-cell called **capitulum** from which 3 to 6 **secondary capitula** project and each of these again gives rise to 2 to 5 long unbranched **filaments.** A filament consists of many cells, each of which liberates a single **biciliated antherozoid.**

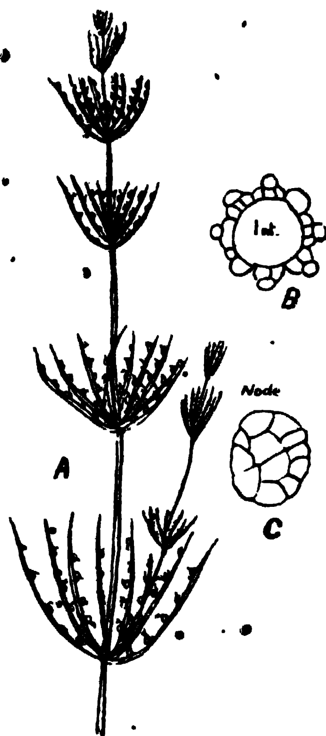


Fig. 199.
Chara. A—Stem with leaves and branches. B—Cross-section of an inter-node C—Section of the node.

The female organ or oogonium, called **nucule**, consists of a central egg-cell and five spirally twisted cells surrounding the oogonium. A cell is cut off from the head of each of the five and thus a five-celled crown is formed at the apex through which antherozoids make their way to effect fertilisation.

The resulting oospore divides at first to form two cells, one of which forms the primary rhizoid while the other elongates, becomes green

and forms the **pro-embryo.** This develops two nodes—the lower one produces the rhizoids and the upper one gives rise to a whorl of branches.

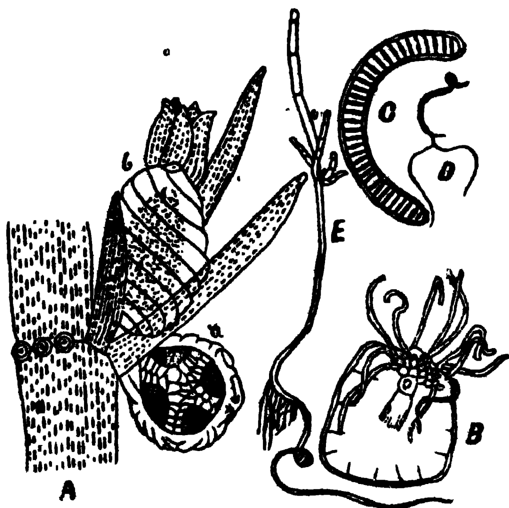


Fig. 200.

Reproductive organs of Chara. A—Portion of the plant. a—Globule. b—Nucule. B—A sheild of a globule with manubrium, capitulum, secondary capitula and filaments. C—A filament with cells. D—One biciliated spermatozoid. E—Germinating oospore.

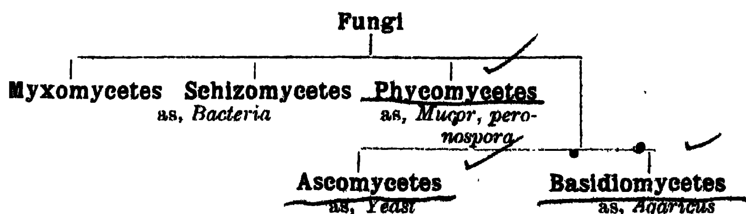
FUNGI

We have seen before that the Fungi are mainly characterised by the total absence of chloroplasts. We have also noticed their parasitic and saprophytic modes of nutrition.

Sometimes, when they live in intimate relationship with Algae or with the roots of higher plants by obtaining from them carbohydrates and supplying the host, in exchange, with nitrogen and other food solution or protecting them in other ways, their mode of life is **symbiosis**. The well-known example of symbiosis can be found in **Lichens** where an alga and a fungus live together. When the Fungi are associated with the roots of higher plants in such a way that the plant obtains the whole of its food by the help of fungus threads, thus playing the part of root-hairs, the symbiosis is called **mycorhiza**. (see page 314)

As the Fungi are land plants, they are usually adapted to aerial conditions. Their gametes are not mostly ciliated and the spores, they bear, are usually dispersed by wind.

Fungi may be classified in the following ways :—



FUNGI—ASCOMYCETES

YEAST.

General characters.—This is a very simple unicellular fungus which grows as a saprophyte on any sugary fluid and can be seen only under the microscope. Each cell forming a single plant is more or less oval containing protoplasm, vacuoles and oil globules. The nucleus is not so distinctly noticed.

The plant has the power of setting up alcoholic fermentation in sugar solution. Thus, when Yeast grows in sugar solution, the sugar is decomposed forming alcohol, carbon dioxide, glycerine etc. Carbon dioxide gas appears on the surface in the form of bubbles. The frothy appearance of the date juice in a jar is a common observation. Owing to this property of exciting fermentation in sugar and starchy substances Yeast is largely used in bakery and distillery.

Reproduction.—

(1) **Budding** or **gemmation** or **pollulation.**—This is the common mode adopted by the plant. So long as the plant is well-provided with food materials, it multiplies by budding very rapidly. From one or more sides bud-like bodies develop from a cell. They grow in size and when they are in the form of their mother cells in structure and contents, they may detach themselves to form separate plants. The daughter cells in their turn, repeat the same process. They may also remain attached to each other forming a chain of cells or a colony.

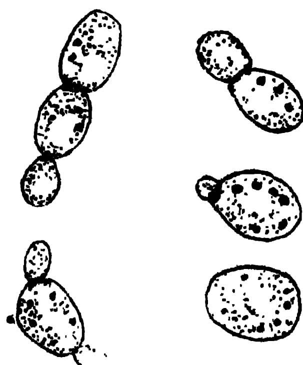


Fig. 201.
Yeast plants multiplying in sugar solution by budding

(2) **Asexual.**—When there is the scarcity of food materials, the plant takes recourse to this method. The nucleus at first divides

into four, round each of which protoplasm aggregates and forms four spores called **ascospores** or **resting spores.** These are formed by the process of free cell-formation and the mother cell is known as **ascus.** Under favourable conditions, the free spore germinates and goes on producing buds or new plants.

(3) **Sexual** :—Very rarely this method is noticed in the plants. Two cells, lying very close to each other, put out short beaks which approaching each other meet to be fused to form a passage. The contents of the two cells now pass through the passage and conjugate forming a **zygospore** which soon is converted into an ascospore.

FUNGI—PHYCOMYCETES

A. MUCOR MUCEDO (mould or *chhata*)

General characters.—This is a common fungus growing as a saprophyte on decaying or rotten organic matters as dung, bread, leather and milky substances. If a piece of moist bread or a shoe be kept in a dark warm room for a few days, it is found that the whole surface of the bread or shoe is covered with a white web-like mass commonly known as mould (*chhatta*). Under the microscope it is found to consist of many interwoven threads called **hyphae.** Some of the threads spread over the substratum on which the plant preys and thus they act as a branched stem. Other threads penetrate into the organic matters in order to draw nourishment thus functioning like roots. The

whole structure formed by the hyphae is known as the **mycelium.** The plant-body is a **coenocyte**, as the protoplasm in the branched tube is continuous and multinucleate. Partition walls are no-where found. The vacuoles and oil globules are present in the protoplasm.

Reproduction.—

(1) **Asexual.**—The long aerial pin-like threads are the reproductive hyphae which grow erect from the mycelium. The head of each hypha swells and the protoplasm with many nuclei fills up the swollen head called **gonidangium** or **sporangium**. The long stalk bearing it is the **gonidiophore**. A new wall, formed beneath the the gonidangium, separates it from the stalk. The protoplasm in the head now divides and forms many cells called **gonidia** or **spores**. The separating wall protruding into the head forms a **columella** which, when the spores are mature, becomes more globular and presses on the head. Thus, the head bursts open and allows the spores to escape. Each spore, falling on a suitable substratum, germinates to produce a new Mucor plant. This method will go on so long as the plant is well-nourished.

(2) **Sexual—conjugation.**—The plant adopts this method in order to make provision against drought. Two neighbouring hyphae approach each other and a wall cuts off from each a small cell at the end which forms the **gametangium**. The two gametangia meet and have the common wall absorbed at the tips. The protoplasmic contents, in the meantime, form in each two undifferentiated gametes which now come together and conjugate forming a

round **zygospore**, as the result of conjugation. The zygospore, when fully developed, acquires two coats—the exospore and the endospore. The exospore is thick and warty in appearance. After a period of rest, the exospore

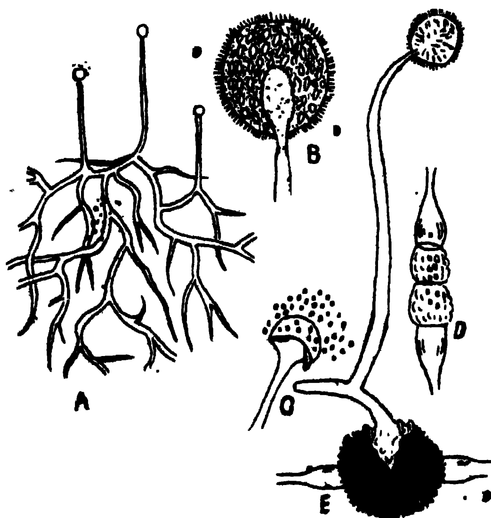


Fig. 202.

Mucor plant. A—Web-like mycelium with aerial hyphae. B—A sporangium with spores and a columella in the middle. C—Spores coming out of the sporangium. D—Two gametangia meeting at their ends. E—Pro-mycelium with a sporangium at the head as the result of the germination of a zygospore.

bursts and the endospore grows out to form a short hypha called **pro-mycelium** which gives rise to a sporangium from the spores of which new plants are formed in the same way as found in the asexual method.

(3) **Parthenogenesis.**—When conjugation fails, one of the gametes may act like a zygospore from which ultimately a new plant is developed.

(4) **Torula condition.**—When the plant is found to grow in any nutritive solution, septa are formed dividing the hyphae into many cells called **oidium cells** which multiply and act like yeast plants in producing alcoholic fermentation.

B. PERONOSPOREAE

General characters :—**Peronospora** and **Phytopthora** are common parasitic plants of the group. Phytopthera is responsible for the potato disease. Peronospora attacks the leaves of grapes and many other flowering plants causing certain diseases.

The discolouration and the formation of velvety patches on the leaves reveal the diseased condition. The mycelium is coenocytic. It ramifies between the cells of the mesophyll and sends the hyphae into the interior of those cells for the rapid absorption of their contents. Thus, the vegetative body is internal.

Reproduction

(1) **Asexual** :—At the time of reproduction, erect hyphae come out through the stomata of the leaves and form branches each, bearing a single gonidangium at the tip. The gonidangia are carried about by currents of air and when they fall on other leaves, the hyphae are produced directly on germination which penetrating into the tissues of the plant begin their ravage. Thus the gonidangia act just like gonidia. In some cases, gonidangium gives rise to biciliated zoogonidia. In Phytopthora, the hyphae bearing gonidangia are branched and several gonidangia appear on the branches.

(2) **Sexual** :—The sexual organs develop and remain within the host. One end of a hypha swells and a cell is cut off at the end by a wall. This forms the **oogonium** in which the central ovum is surrounded by a peripheral layer of protoplasm called **periplasm.** Another hypha, cut off by a wall at its end in the same way forms the male organ or **pollinodium** in which the male gamete is covered by periplasm as



Fig. 203.

Phytopthera (Peronosporeae). A—The plant attacking the mesophyll with aerial hyphae coming out through the stomata. B—Gonidangium. C—Gonidangium in the act of division. D—Gonidangium producing biciliate zoogonidia.

in oogonium. The pollinodium grows to come in contact with the oogonium when it puts out a tube to pierce through the wall of the latter and to effect fertilisation by the discharge of its contents. The oospores, when ready for germination after a period of rest, are liberated by the infected leaves which perish at that time.

FUNGI—BASIDIOMYCETES

AGARICUS CAMPESTRIS (Mushroom or *Banger chatta*)

General characters.—This is a very common saprophytic fungus. It grows abundantly on decomposing or rotten organic substances in damp woods where the soil is rich in vegetable matter. The vegetative body or mycelium of the plant consists of many threads which penetrate and form a network in the organic matter or humus of the soil on which the plant lives. The hyphae of the mycelium are incompletely septate so they consist of several coenocytes. Each coenocyte contains protoplasm with many nuclei, vacuoles and oil globules. The aerial parts of the plant which we call *banger chhata* are its reproductive organs. Some varieties of the plant are edible and are cultivated for this purpose. Other varieties are highly poisonous.



Fig. 204
Reproductive bodies of mushroom.

Reproduction.—

(1) **Asexual.**—At the time of reproduction, many aerial hyphae growing up unite together to form a massive stalk, called **stipe**. At the head of the stalk, there is a spreading umbrella-shaped protuberance, called **pileus.** From the under surface of the pileus there are many thin

plates radiating from the stalk to the end of the pileus. These are called the **gills** as they resemble the gills of fishes.

Taking a cross section of a gill, it is found that the central part is occupied by long hyphal cells, all of which diverge right and left and terminate into a layer of round cells on two sides. The central part is called **trama** while the layers on two sides form **sub-hymenium**. Outside this, there is again another layer of closely arranged club-shaped cells standing at right angles to the sub-hymenium. This layer is called **hymenium** the cells of which are of two kinds. Some are barren and are called **paraphyses**, others are **basidia** on each of which occur two or four outgrowths called **sterigmata**. Each sterigma bears at the end a **gonidium** or spore usually known as **basidiospore**. A spore germinating on a suitable place grows out into a new plant.

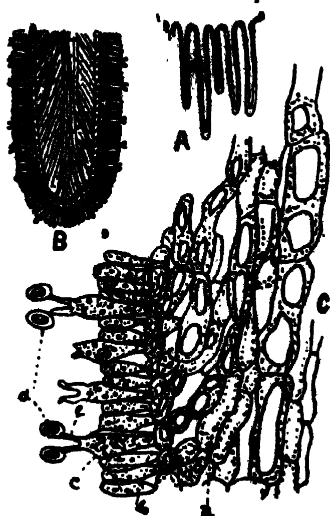


Fig. 205.
Gill of Mushroom. A—Gills. B—One gill magnified. C—Further magnified. a- Trama. b—Hymenium just out the layer of sub-hymenium. c—Basidium. d—Basidiosporse. e—sterigmatum.

There is no other method of reproduction known in the plant.

ALTERNATION OF GENERATIONS

Plants, higher or lower, are to pass through several stages in their lives from the beginning to the end. These stages, specially in connection with the methods of reproduction, adopted by the plant, form its life-history.

The life-history of most plants, when studied, shows two distinct phases to complete the whole course of the life. In the lowest forms of plants which we have studied under Thallophytes, some have distinct male and female reproductive organs by means of which they reproduce themselves. Such sex-bearing plants are called **gametophytes** because they bear sexual cells or **gametes**. We have also seen stages in which the plant bears **spores** in order to multiply. Such spore-bearing plants are called **sporophytes**. The Vaucheria, when it reproduces itself by sexual cells, behaves like a gametophyte, but at another stage it is found to reproduce itself by means of zoospores when it behaves like a sporophyte. This behaviour is also noticed in Ulothrix and other plants. But in such plants only one phase may be found to complete the whole course of the life. We shall find presently by studying higher plants above Thallophytes that their life-history includes both the stages of gametophyte and sporophyte—one leading to the other. The gametophyte produces male and female gametes which by their union give rise to the sporophyte. The sporophyte, on the other hand, bears spores which on germination give rise to gametophyte. Sporophyte and gametophyte are thus the two phases which regularly alternate with each other in the lives of all

plants excepting the Thallophytes. This alternation, exhibited in the life-history of any plant, is known as **alternation of generations.**

These two alternating forms are not equal in their degree of development in the lives of all plants above Thallophytes. In Thallophytes, lower in the scale of Bryophytes, the alternation is quite irregular and the gametophyte is a very prominent form. It is only in the Bryophytes that the two forms develop equally. Above Bryophytes, there is a tendency of the greater development of the sporophyte. Consequently, the gametophyte becomes more and more inconspicuous or reduced, as we advance towards the higher plants in the scale. Thus, in the flowering plants, the gametophyte is so reduced that it cannot easily be traced.

BRYOPHYTES

The plants of this group are not so undifferentiated as the Thallophytes are. Though the plant body, in some Bryophytes, is thalloid, there are distinct stems and leaves in other plants. The roots are not true. Internally, the body consists of many cells differentiated into tissues. The true vessels as found in higher plants, are never formed in them. The plants, thus, occupy a position intermediate between the Thallophytes or cellular Cryptogams and Pteridophytes or vascular Cryptogams. They are, thus, neither cellular nor vascular.

Bryophytes are further distinguished from the Thallophytes by their characteristic structures of the sexual organs, antheridia (male) and archegonia (female). These

organs are also differentiated in the Pteridophytes, which along with the Bryophytes exhibit regular alternation of generations. Both of them multiply sexually by gametes and asexually by spores. These two modes of reproduction, sexual and asexual, occur in regular alternation.

The plant-body is the gametophyte which, unlike that of higher plants, is differentiated into stems, leaves and root-like structures called **rhizoids**. The sporophyte develops as a fruit-like body. That the vegetative growth takes place in the sexual stage is a peculiarity in these plants. The sporophyte is not an independent body. It grows on the gametophyte as a partial parasite, for it is to draw part of its required food from the gametophyte. When the spores germinate, they give rise to a flat plate-like body or a much-branched filament called **protonema**. On this, plants arise as lateral buds.

The group comprises two classes :—(1) Mosses and (2) Liverworts.

The MOSS

Type—**Funaria**.

Gametophyte.

The plants grow in a colony, in the form of a green carpet-like mass, on the damp surface of old walls, rocks, etc., specially during the rainy season, when they are constantly supplied with water. Each small plant is scarcely half an inch long. On the erect slender stem, there are numerous small green leaves arranged spirally. The true roots are wanting. The hairy root-like structures arising from the base of the stem are known as **rhizoids**.

As the sexual organs appear directly on the plant, the differentiated plant-body is the gametophyte. This plant is monoecious. In the midst of a cluster of leaves at the head, there appear several male organs or **antheridia** in the form of club-shaped bodies. They are accompanied by stalked globular-headed bodies called

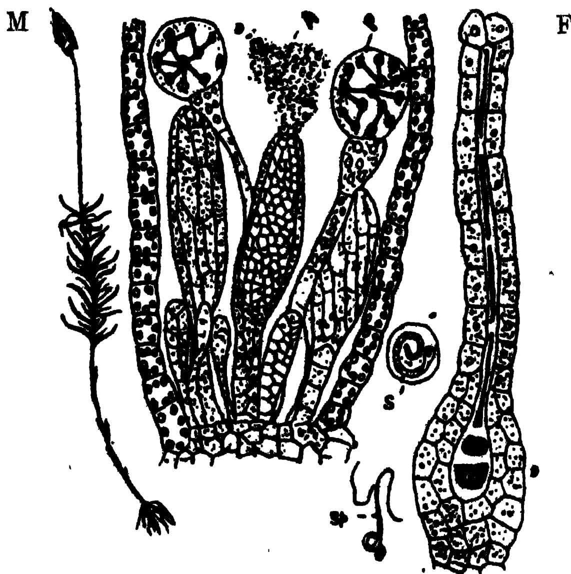


Fig. 206.

M—Moss plant with capsule. A—Antheridium liberating sperm rtozoids. P Paraphyses. S—Spermatozoid within the mother cell. Sp Swimming spermatozoid. F—Archegomium with venter, neck and canal.

parphyses which help the development of antheridia by the secretion of moisture. An antheridium consists of a wall which surrounds the central cells, each of which after divisions gives rise to several mother cells.

In each mother cell, called **spermatocyte**, one antherozoid also called **spermatozoid** is formed. When the antheridia are mature, they dehisce to liberate the **biciliated** spermatozoids which now move freely in the rain drops or dew films by means of their cilia.

In the same way, several archegonia or female organs appear on stalks amongst a terminal cluster of leaves of a lateral branch. An archegonium is a flask-like body with a long neck. It consists of three parts. The swollen basal region is called **venter** which contains a naked cell, called **ovum** ; the **neck** or the projecting part encloses a row of central cells which form the **canal** leading down to the ovum. When the ovum is mature, the canal cell-walls become disorganised making a continuous mucilaginous path in which cane sugar appears as an attractive substance for the swimming spermatozoids.

One of the spermatozoids, when attracted, plunges down into the canal and fertilises the ovum to produce **oospore** as the result.

Sporophyte

The oospore divides to form an **embryo**, the upper part of which enlarges and forms a **capsule**, while the lower part forms a slender **stalk or seta** which terminates below in a more or less well-developed **foot**. The **sporogonium** representing the sporophyte of the plant. thus, consists of capsule, seta and foot. It has no separate existence. It lives as a semi-parasite on the head of the plant from which it is to gather part of the required nutritive food. The seta, attached to the plant, is for drawing the food by the help of

the foot which acts as a **haustorium**. The remaining food is obtained from the atmosphere, the CO_2 of which is made use of by the chloroplasts of the capsule.

The young capsule has a conical hood called **calyptra** which arises from the growing venter of the archegonium. This is pushed off as the capsule expands. There is a lid called **operculum** on the top of the capsule connected by a

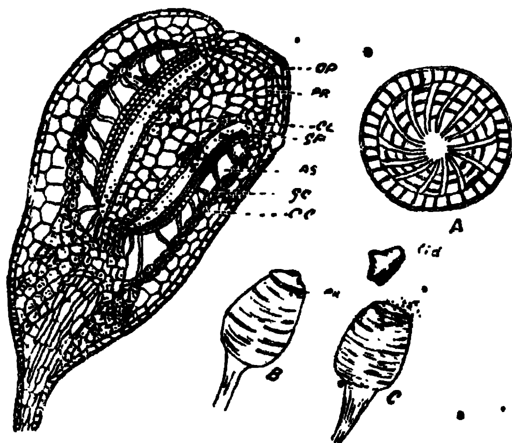


Fig. 207.

Capsule of Moss. Op—Operculum. PR—Peristome. CL—Columella. Sp—Spore-producing tissue. AS—Air space. GC—Bridge-shaped cells. CC—Chlorophyll-containing cells. A—Peristome (magnified). B—Entire capsule with lid and peristome (PR). C—Capsule with the lid thrown off and the spores ejected.

ring of cells called **annulus**. At the mouth of the capsule, below the lid, there is a set of teeth which form **peristome** converging from the circumference towards the centre. The teeth, being hygroscopic, help in the dispersal of spores by bending inwards and outwards. A nutritive central mass

of tissue called **columella** in the form of a cylinder, runs from the middle of the capsule to the operculum. Outside this is the **sporogenous tissue,** the cells of which, after direct divisions, produce **spores,** 4 in each cell. This is surrounded by a complex wall which consists of, besides other cells on the periphery, a large **air space** traversed by thin filamentous **strands of cells**. The base of the capsule is solid, while in

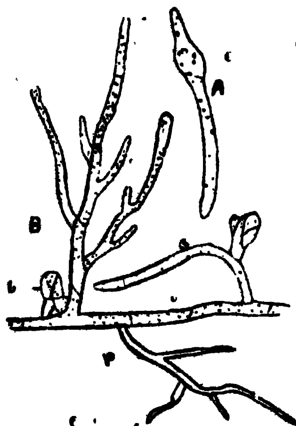


Fig. 208.

Protonema of Moss. A—Spore germinating. B—Much-branched protonema. b—Bud. r—Rhizoid.

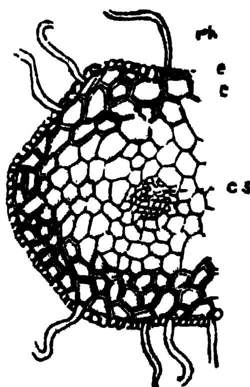


Fig. 209.

Cross section of Moss stem. rh—Rhizoid. e—Epidermis. c—Cortex. cs—conducting strand.

the upper portion, the central columella, with the spore-producing tissues, is separated from the wall by the air space.

The capsule, when ripe, throws off the lid and the mature spores escape aided by the peristome. On germination, each spore gives rise to a much-branched filamentous body called **protonema.** On this, many buds appear as lateral outgrowths. Each bud grows out into a new plant.

The alternation of generations is shown in the table.

Stem structure.—The outermost layer corresponds to **epidermis** from which **rhizoids** are given off. Next to this, is the **cortex** consisting of **thin-walled** cells, but the upper few layers are **thick-walled**. In the centre, there

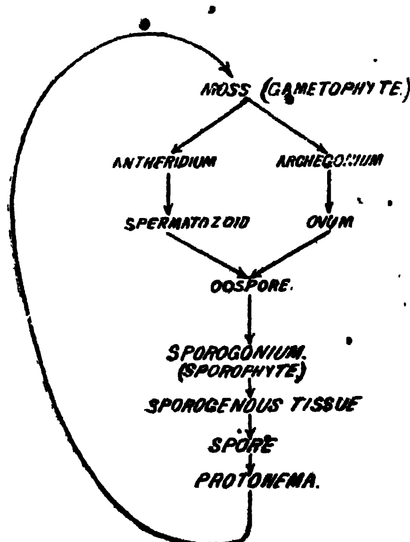


Fig. 210.

Graphical life-history of Moss.

is the **conducting tissue** corresponding to the stele of higher plants. This consists of **several strands of cells which act like xylem and phloem.** In some cases, the thick-walled strands are surrounded by several thin-walled cells. This differentiation may correspond to the differentiated xylem and phloem in the higher plants.

LIVERWORTS

TYPE—MARCHANTIA

General characters :—

Marchantia, a type of Liverworts, is a moisture-loving simple bryophyte growing always in damp places. It is a green flat **thallus** branching **dichotomously**. The thallus is prostrate, complex in structure and **dorsiventral**, i. e., with two unlike surfaces dorsal and ventral. The dorsal or upper surface, exposed to light, develops chlorophyll and performs assimilation, but the colourless ventral surface lying on the substratum sends out scales and rhizoids for fixture and absorption.

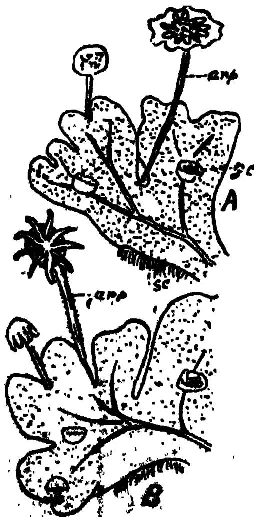


Fig. 211.
Marchantia thallus. A—With antheridiophore (anp). B—With archegoniophore (arp). Gc—Gemmae cup.

Thallus structure

The **rhizoids** and **scales** arise from the single layer of **lower epidermis**. Above this, there are several layers of **colourless cells**, those of

which nearer the upper surface contain **starch grains**. At places, a few colourless cells are filled with **mucilage.** The upper surface is differentiated into large hexagonal **air-chambers** which are separated from each other by **partitions of colourless cell.** From the floor of each chamber **chlorophyll-containing cells** grow up in the form of filaments. The chamber is roofed by a **single layer of epidermis** which is pierced in the middle of each chamber by a large **air-pore** bounded by several layers of cells.

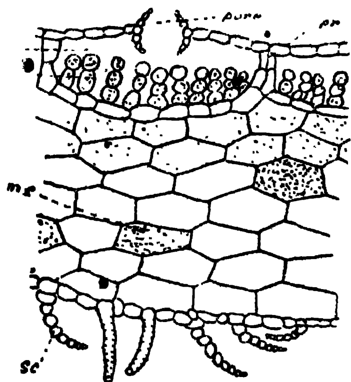


Fig. 212.

Section of Merchantia thallus pr—Partition wall. a—Air space. cc—Chlorophyll-containing cells. mc—Cell with mucilage. Sc—Scale.

On the upper surface of the thallus, small cups, known as **gemmae cups** containing biscuit-shaped multicellular buds appear. These modified buds, when mature, fall off and give rise to new plants vegetatively. In many Mosses also, gemmae are formed to effect vegetative multiplication.

Gametophyte

The thallus is the gametophyte which is dioecious. The male and female sexual organs appear on two different individuals. Directly from the thallus leafless branches, called **gametophores**, grow up, each bearing a disc at the

head. The gametophores are **antheridiophores**, as they bear antheridia. The discs in these cases are flat and lobed. The gametophores, bearing archegonia, are **archegoniophores**, the discs of which are rayed or star-shaped.

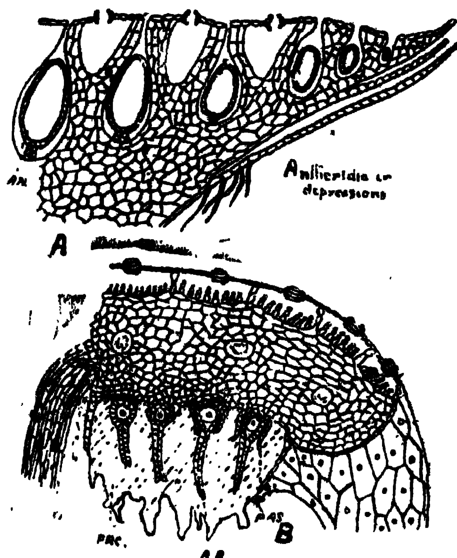


Fig. 213.
Reproductive organs of Merchantia. A—Antheridia B—Archegonia. an—Antherdium. PRC—Perichaetium. P—Perigynium. AR—Archegonium.

The development of antheridia and archegonia occurs broadly in the same way as in the Mosses. They differ in the following points :—

(1) The antheridia, developing on the lobed discs, are not within a cluster of leaves, as in Moss, but within large

flask-shaped cavities, one in each cavity, which opens on the upper surface by small aperture, called **ostiole**.

(2) The archegonia, developing on the back of each ray, are enveloped by a membranous outgrowth from the disc, called **perichaetium**.

(3) Another outgrowth appears from the base of each archegonium, called **perigynium**.

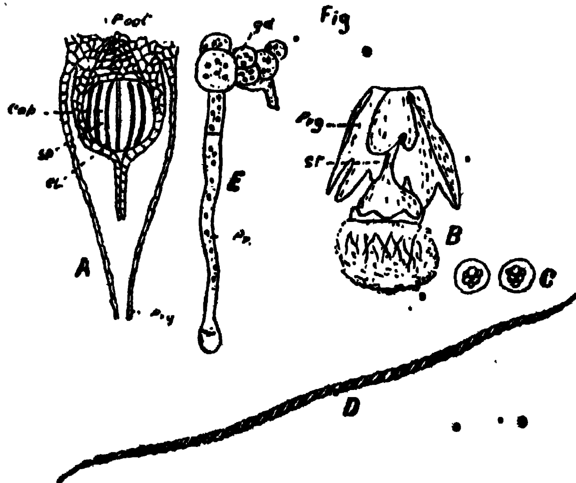


Fig. 214.

Sporogonium of Merchantia. A, B—Sporogonium developing. Cap-Capsule. Sp—Sporogenous tissue. El—Elaters. St—Stalk. C—Spores. D—Elater. E—Spore developing. Pr—Protonema. Gd—Germ-disc. Prg—Perigyrium.

Fertilisation occurs as in Moss. The oospore divides itself into upper and lower cells. The lower cell forms the **foot** and a short **seta**, while the upper cell gives rise to **capsule** only. The **perigynium** grows further after fertilisation and surrounds the capsule as well as the

calytra formed by the growing venter. The capsule is not so complicated as in Moss. The columella, air-space, traversing strands of cells, operculum, peristome, etc., are altogether absent. The contents of the capsule are differentiated into spores and long, spirally thickened sterile cells, called **elaters,** which help the dispersal of spores by their hygroscopic movements. The dehiscence of the capsule is irregular. On germination of the spore, it produces a small and short-lived **protonema**, which is not branched as in Moss. The protonema produces a plate of several green cells, called **germ-disc** which gives rise to a new plant.

PTERIDOPHYTA

Pteridophytes, also known as vascular Cryptogams, have their bodies distinctly differentiated into roots, stems and leaves. At the time of reproduction, a special reproductive shoot usually arises on which sporophylls develop. Most of the Pteridophytes bear one kind of spores. They are called **homosporous.** Others are **heterosporous** as they bear two kinds of spores. **Ferns, Equisetum, Lycopodium** are homosporous, while **Selaginella, Marsilea** are heterosporous. When there are two kinds of spores, the **microspore gives** rise to a gametophyte, called **male prothallus;** on which male organs or **antheridia** develop. The **microspore,** on the other hand, gives rise to a **female prothallus** to bear on it the female organs or **archegonia.** **The alternation of generations as exhibited by the plants is well-defined and regular. Here all the stages of the two generations are well-represented as in Bryophytes.**

The important plants of this group are :—(1) **Ferns,** (2) **Equisetum** (3) **Selaginella** (4) **Lycopodium**

FERNS

General characters

Ferns usually grow everywhere but are more abundant in cold climates and in hilly places. There are numerous kinds of Ferns some of which are tree-ferns growing like palms. Some are climbing epiphytes. Most of them have rhizomous stems from which many fibrous roots grow. The only visible structures are their large, beautiful, compound and pinnate leaves called **fronds.** While young, the leaves are coiled like the tail of a dog, hence the ptyxis is **circinate**. There is no lateral branching, though buds may arise on the petioles which are then branched. The stems and leaf-petioles are usually covered with brown chaffy hairs called **ramenta**.

Sporophyte

The plant body itself is the sporophyte bearing spores of one type. The plant thus is homosporous.

The green leaves are not only assimilatory but may be also reproductive as, on the back of them are produced minute dot-like structures in which spores are formed. These structures are called **sori** (sing.—sorus) and the leaves bearing them are called **sporophylls**. Each sorus, when carefully examined under the microscope, is found to consist of a collection of several stalked capsular bodies, called **sporangia**, which are usually covered by an umbrella-shaped scale called **indusium** arising from the leaf on a group of cells, called **placenta**.

Each sporangium arises from a single cell of the placenta. Its capsule is covered with a single layer of

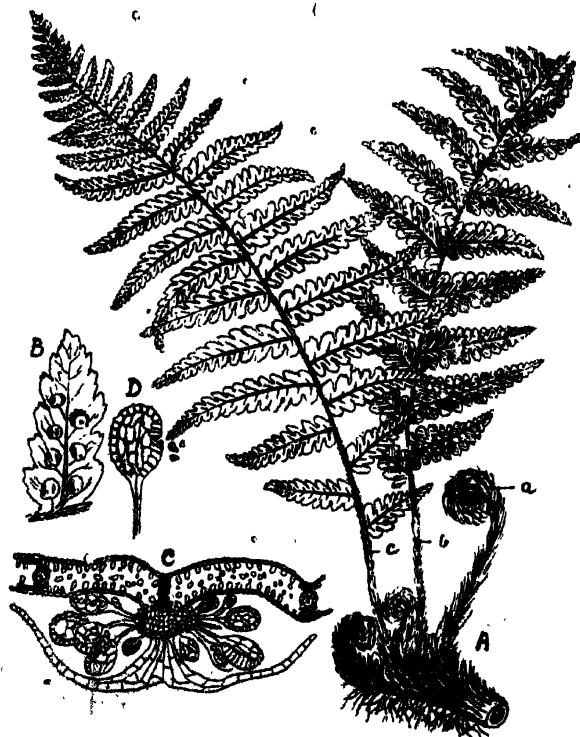


Fig. 215.

Fern plant. A—Fern rhizome with leaves. a—Young leaf showing circinate ptyxis. b—Leaf showing its back surface with spores. c—Leaf showing front surface with no spores. B—Leaflet showing sori. C—Sorus and indusium. D—One sporangium bursting and liberating spores.

cells; and at its margin can be distinguished a specialised row of thickened cells forming an incomplete ring which is

known as **annulus**. Within the capsule, there are many mother cells each of which contains **four spores**. When ripe, the sporangium bursts, due to the contraction of the annulus and the mature spores are set free. A spore has two coats,—the outer is called **exospore** and the inner, the **endospore.**

Gametophyte.

On germination of the spore on moist soil, the exospore bursts and the endospore protrudes to form

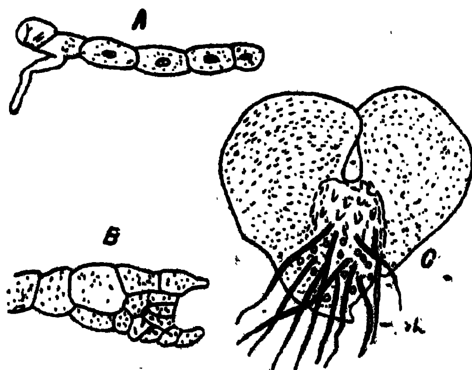


Fig. 216.
Prothallus of Fern. A—Spore germinating and producing green cells and rhizoids. B—Developing filament. C—Prothallus with shizoids (rh) and sexual organs.

a short green **filament**. This goes on developing and soon it assumes the shape of a flat, heart-shaped body, called **prothallus**. This is fixed to the soil by a number of unicellular hairs **called rhizoids** growing from the under-surface. Having chloroplasts and rhizoids for the absorp-

tion of food from air and soil respectively, the prothallus leads an independent life having no connection with the Fern plant or the sporophyte. This prothallus is the **gametophyte** of the plant, as its function is to bear the gametes on it. On the under surface of the prothallus

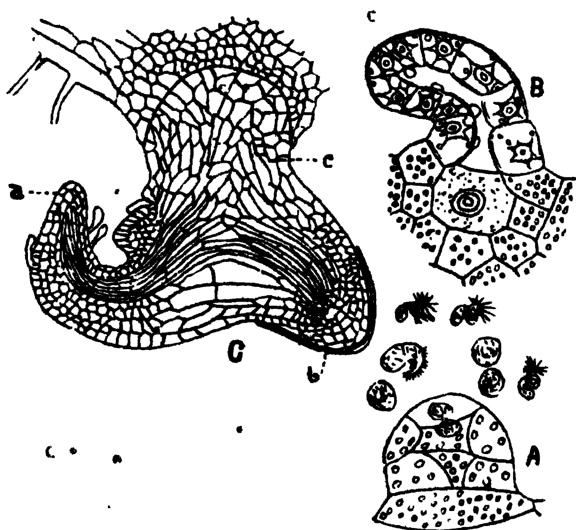


Fig. 217.
A—Antheridium liberating spermatozoids. B—Archegonium. C—Embryo of fern. a—Primary stem with leaves. b—Primary root. C—Foot.

two types of reproductive organs appear. The female reproductive organs or archegonia are flask-spaped and can be found near the notch of the prothallus ; while the male reproductive organs or antheridia are globular and can be found among the rhizoids.

An antheridium has the same structure as in Moss. The spermatozoids here are **multiciliated**. They go on moving in water by means of cilia. Each archegonium consists of (a) **venter**, the basal swollen portion containing **ovum** or the female cell, (b) **neck** and (c) **canal** belonging to the neck and venter. When the ovum is mature, the neck breaks open and the canal is filled with mucilage containing **malic acid** which attracts the moving spermatozoids.

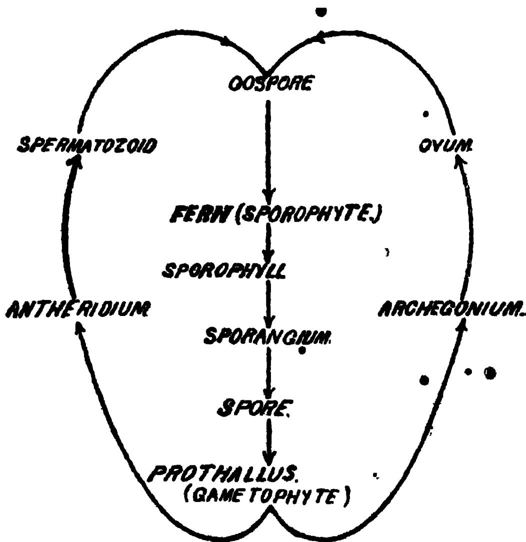


Fig. 218.
Graphic representation of the life-history of Fern.

When the spermatozoids are thus attracted, one of them makes its way into the canal of one archegonium to reach the ovum which is then fertilised. The result is the **oospore**, which after divisions, forms the embryo of the

plant. The embryo, after development gives rise to a young Fern plant. A temporary absorbing organ called **foot** is found to develop in order to absorb nourishment from the prothallus for the embryo.

The alternation of generations is very clear and regular. The plant itself is the sporophyte while the prothallus is the gametophyte. As the spores are of one type, the gametophyte has only one form. Both the sporophyte and gametophyte are separate and independent as if they are two different plants. They represent the two generations of the life cycle of the plant.

The above table shows how the alternation occurs in the life-history.

Apospory and Apogamy

It is sometimes observed in Ferns, that the method of reproduction adopted by the plants is not regular, Thus in some cases, without the formation of reproductive organs, the prothallus gives rise to a new plant. This condition is known as **apogamy**. Again, there are cases where the prothallus is directly formed on the leaf without the intervention of sporangia and spores. This is known as **apospory**. Plants also multiply vegetatively by the adventitious buds developed on the leaf-base.

EQUISETUM

Sporophyte

This plant is a native of marshy places in cold climates and can be found in the Himalayas. Specimens have also been found near Calcutta. The stem is a much-branched

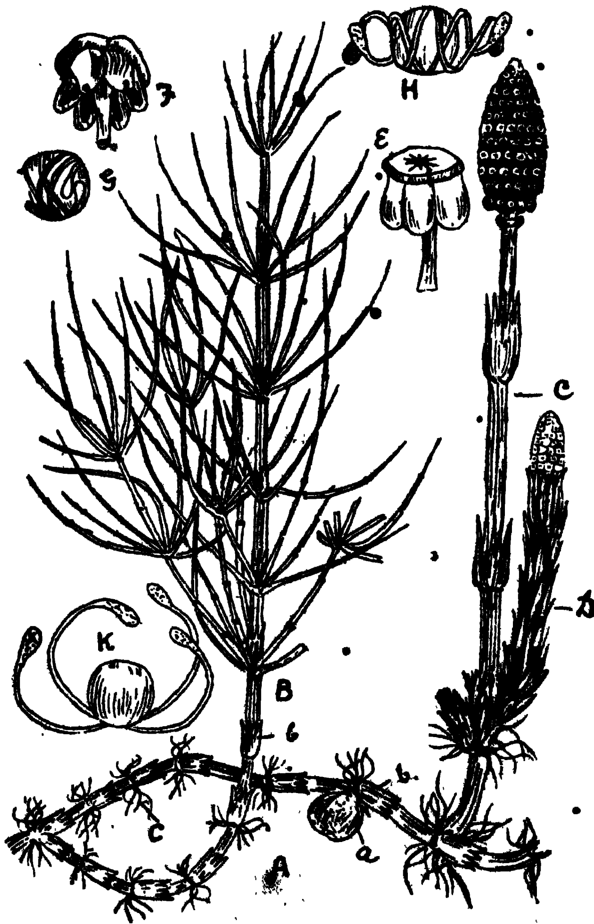


Fig. 219

Equisetum. A—Rhizome. a—Tuber. b—Leaf sheath. c—Adventitions roots. B—Aerial shoot. C—Festile shoot. D—Young cone. E—Sporophyll. F—Sporophyll showing mature sporangia. G, H—Spores with bands. H Four elaters of a dispersed spore.

rhizome with distinct nodes and internodes. At every node there is a whorl of scaly leaves which are united to form a **sheath** round the stem. In the axil of the sheath, branches arise in whorls. Adventitious roots are given off from the nodes of the rhizome. Erect aerial shoots grow up from the rhizome and they are of two kinds. Some are much-branched green, vegetative shoots, while others are unbranched reproductive shoots known as the **cones** or **spikes** of the plant. The leaves develop in the same way as in the rhizome.

Each spike is terminated by a collection of densely crowded **sporophylls**, which arise in different whorls forming a cone-like mass. Each sporophyll is stalked, peltate and disc-like to the underside of which several sporangia are attached, all turned to the axis of the shoot. The sporangia contain numerous **spores of one kind** only. The last whorl of abortive leaves, just below the cone, forms the **annulus**. When the spores are mature, the outer wall splits up into four hygroscopic bands, called **elaters,** which coil spirally round the spore. They help the dispersion of the spores.

Gametophyte

The spores germinate to produce **prothalli of two kinds**. Some of the spores produce prothalli on which antheridia are developed. Others produce prothalli on which archegonia are formed. Thus, the prothalli are **dioecious**. It has been observed, however, that in some cases, the same prothallus that bears antheridia as one time produces archegomia later in season. Compared with those of the Fern

the prothalli are irregular in forms. The male prothalli are smaller in size than the female ones. The antheridia with spermatozoids, and archegonia with their female gametes agree closely in structure and development with the corresponding organs in the Ferns.

The alternation of generations occurs in the same way as in Ferns. The plant also multiplies vegetatively by the formation of tubers at the nodes of underground rhizomes.

SELAGINELLA

Sporophyte

(a) **Vegetative shoot.** The plant itself is the sporophyte. It usually grows in forest regions or in hot houses. It is common in many gardens. Its stem is slender, creeping and clothed with many small leaves in four rows. The leaves, in two rows, on the upper surface, are smaller than those in the other two rows on the two sides of the stem. The branches are really lateral though they look to be dichotomous. From the base of the branches root-like organs called **rhizophores** develop. Though they have no root-cap, these colourless and leafless bodies grow down to the soil but they resemble stems in their internal structure. There is a **ligule** near the base of each leaf.

(b) Reproductive shoot or spike of Selaginella.

Some of the branches grow erect and form the reproductive shoots. They differ from other branches in this that their spirally arranged leaves are all similar in size bearing sporangia at the axils. These are called the **spikes** or **cones** of the plant. At the axil of each leaf one **sporan-**

gium develops from an outgrowth of a little group of cells. Though the leaves or sporophylls are of the same type the sporangia are of two kinds bearing two kinds of spores. The **microsporangium** contains many small spores called **microspores** while the **macrosporangium** contains only **four big spores called macrospores**. Thus the plant is

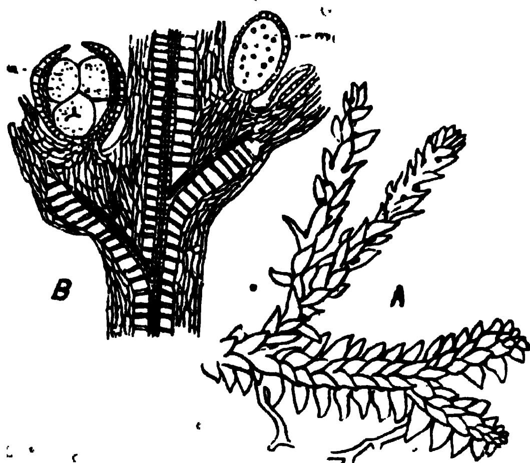


Fig. 220

Selaginella. A--The creeping stem with leaves arranged in four rows and with erect spikes. B—A portion of a spike magnified. mi—Microsporangium. ma—Macrosporangium.

heterosporous. Both the two kinds of sporangia occur on the same spike though in the axils of different sporophylls. The microsporangium, when ripe, bursts open and the microspores come out. When they fall on moist soil they germinate. This microsporangium and its spores resemble closely the anther and pollen grains of Angiosperms respectively both in structure and mode of origin.

Gametophyte

When the microspore germinates, it is divided unequally into two cells. The small cell remains undivided and forms the **prothallus cell. This inactive cell represents the male prothallus.** The other big cell undergoes several divisions resulting the formation of several mother cells

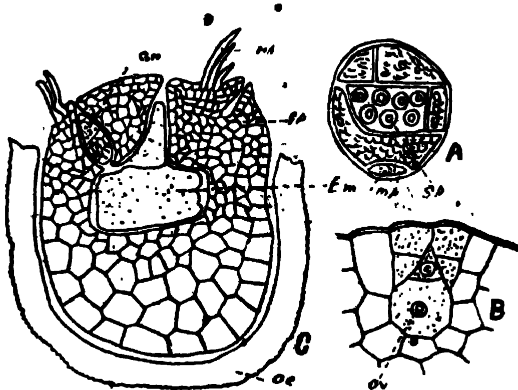


Fig. 221.

A—Microspore germinating. mp—Male prothallus. sp—Spermatozoid mother cells. B—Archegonium. ov—ovum. C—Female prothallus with developing embryo (Em). fp—Female prothallus. Ar—Archegonium. rh—Rhizoids.

called **spermatocytes** walled by several other cells on the outside. Each mother cell gives rise to a single **biciliated spermatozoid.**

The **macrospore begins to germinate when it is within the sporangium and is shed from it when the germination has advanced.** By the process of free cell-formation a tissue is formed in the spore. This is the **female prothallus.** The cells of it, in the lower region, becoming larger and filled with food materials,form **second-**

ary prothallus. The prothallus gives rise to several flask-shaped archegonia at its top. Each archegonium has a swollen basal portion called **venter**, a **neck**, and a **canal**. The venter contains a single naked cell, the **ovum**.

Now the macrosporangium bursts and the spore comes out to fall on the ground. The spore ruptures at its apex due to the growth of the prothallus which protrudes slightly,

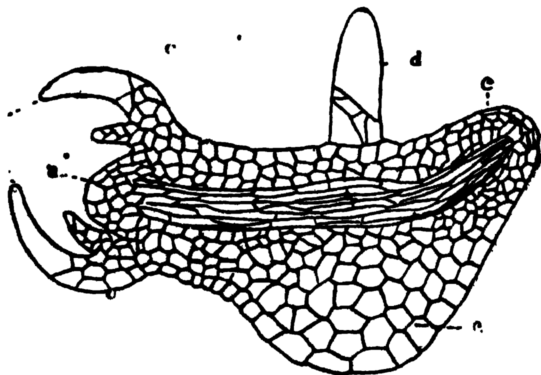


Fig. 222.

Selaginella embryo. a—Stem. b—Leaves. c—Root. d—Suspensor. e—Foot.

becomes green and produces a few rhizoids. The archegonia are thus exposed.

The spermatozoids, liberated from their mother cells, move about by means of their cilia. Attracted by the mucilage in the canal of the archegonium, the spermatozoid fertilizes the ovum and forms an oospore.

The oospore divides and produces an **embryo** as well as a **suspensor**. The suspensor consists of a row of cells meant for pushing embryo downwards so that the latter,

coming in close contact with the secondary prothallus, withdraws food through the help of its **foot**.

Selaginella comes nearer to Phanerogams than do any other Cryptogams in reproduction and general course of development. It thus forms a connecting link between the Cryptogams and the flowering plants.

The alternation of generations is regular and is shown in the following table :—

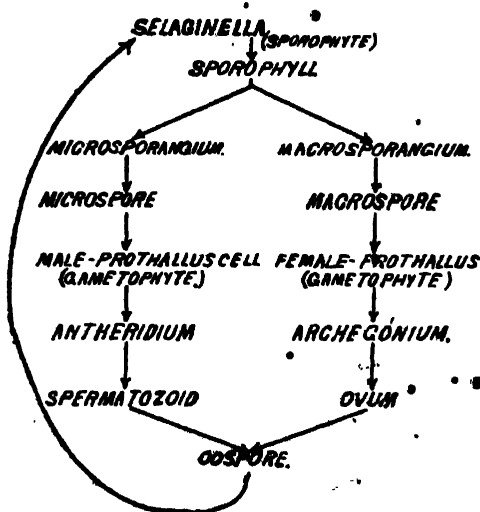


Fig. 223.

Graphic representation of Selaginella life-history.

Lycopodium

Lycopodium or **club moss** agrees mostly with Selaginella, but it differs mainly from the latter in being **homosporous** like Ferns. It grows abundantly in the hills. Some specimens also occur in the Sunderbans. The small crowded leaves are arranged spirally on the

creeping stem which branches **dichotomously** or racemosely. The adventitious roots always branch dichotomously.

A section of the stem shows that within the **epidermis** there is the **cortex**, the upper layers of which are **sclerenchymatous**. The **endodermis** is well-defined within which is a **pericycle** of several

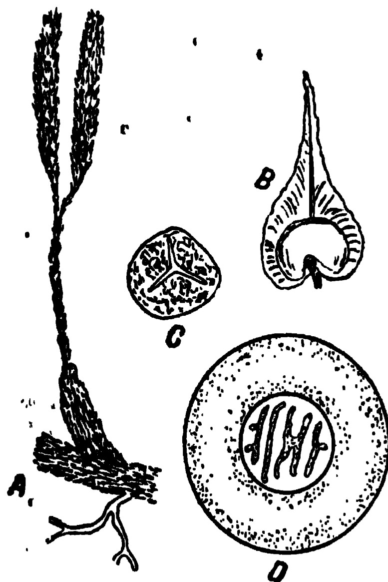


Fig. 224.

Lycopodium. A—Plant with cones. B—Sporangium. C—Spore. D—Section of the stem.

layers. In the central vascular cylinder there are several plates of **xylem alternating with the masses of phloem elements** while the rest of the cylinder is occupied by **parenchyma.**

At the ends of erect shoots forming **cones**, the sporophylls are aggregated. Upon the inner surface of the sporophylls the **sporangia** are placed singly as **kidney-shaped capsules.** The ripe sporangia liberate **tetrahedral spores.**

The **prothallium** is of several types occurring in different species. In some, it is an erect cylindrical body terminating in a crown of green leafy lobes on which the organs appear. In other species, it is a **saprophytic underground body**, which may grow below the bark of decaying branches. **The gametophyte is monoecious.** The organs develop in the same way as those of Selaginella.

Exercise I

1. Explain fully the difference between Algae and Fungi. Give examples of each.—C. U. 1932, 1922, 1913.

2. Compare the vegetative and reproductive structure of any Alga with that of any Fungus known to you.—C. U. 1911.

3. Describe the structure and life-history of Spirogyra.—(C. U. 1929, 1926, 1920), Vaucheria (1914), Mucor (1931, 1927, 1910), Yeast (1930, 1923, 1914).

4. How does Yeast or Mucor differ from a higher plant as regards structure, general mode of life and reproduction.

—C. U. 1927, 1916

5. What is Yeast ? Some yeast cells are put into a solution of sugar and kept in a warm place. Describe the changes that may take place in (a) yeast, (b) in the solution.—C. U. 1920.

Hint :—(a) Yeast cells multiply by budding (b) solution will be changed into alcohol and CO_2 will evolve.

6. Describe the life history of Fern and explain the alternation of generations in the case of Fern.—C. U. 1933, 1932, 1930. 1928, 1925, 1922, 1921. 1920, 1919, 1912.

7. Describe the sporangiferous spike of an Equisetum. Give a neat sketch.—C. U. 1933, 1931.

8. Explain alternation of generations as illustrated in the life history of Moss plant.—(C. U. 1928, 1927, 1924, 1923, 1917, 1914.)

Or, Selaginella—(C. U. 1926).

9. What is sporangium ? Write short note on the occurrence of sporangia in a Fern or a Moss.—C. U. 1919.

10. Compare the reproductive cycle of a Moss with that of a Fern. —C. U. 1925,

CHAPTER II

PHANEROGAMS

The plant-body of Phanerogams possesses two kinds of spores, each of which gives rise to a separate gametophyte, though greatly reduced, one bearing male and the other female gametes. The spores, from which male gametophytes are developed are called **microspores**, while those from which female gametophytes are developed are **macrospores** or **megaspores**. The plant-body of any flowering plant, is thus the sporophyte on which the **microspores are the pollen grains** and the **macrospore is the embryo sac**.

In the flowering plants and most Pteridophytes, special shoots grow up for the purpose of bearing reproductive asexual cells or spores. These spores are borne on special leaves called **sporophylls**. In the flowering plants, the special shoot is the flower, while the **micro-sporophylls** are the **stamens** for bearing microspores, and **carpels** or **macrosporophylls** are for bearing macrospores. The sac-like body, developed on the sporophyll to bear spores in it, is the **sporangium**. The anther containing microspores is the **microsporangium**, while the ovule is the **macrosporangium**, as it contains the embryo-sac or macrospore.

In all flowering plants the macrospores germinate always within their sporangia. This results in the formation of seeds in them. This important peculiarity of the Phanerogams distinguishes them from all Cryptogams. We

have noticed that in all Pteridophytes (excepting Selaginella) the macrospores germinate outside their sporangia. It is for this reason that there is no chance of seed-formation in in those plants.

ANGIOSPERM

Microspore and **Male gamete.**

In the young anther which is four-cornered in its transverse section, several cells next to epidermis divide at each of the corners. The inner cells, produced by this division, become differentiated and form an important layer,

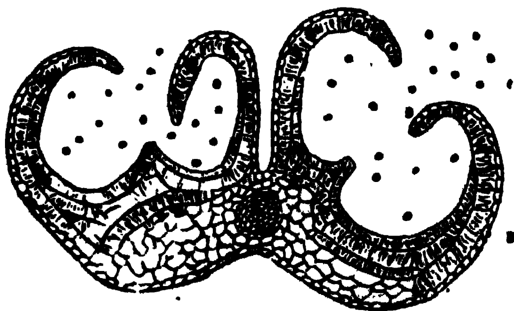


Fig. 225.
Anther dehiscing and liberating the pollen grains.

archesporium, so called because pollen grains or microspores arise from it. The cells, just outside this layer form, after divisions,a surrounding layer called **tapetum** to supply food to the developing pollen grains. The archesporium undergoes several divisions to produce isolated round cells called **pollen-mother cells**, each of which divides by free

cell-formation **four pollen grains**. The walls of the mother cells being dissolved, the cavity of each sac is filled with free pollen grains. When the anther is mature, the wall of each sac consists of two or three spirally thickened **fibrous layers**, besides the epidermis. At the place of separation of the two sacs in the same lobe of anther, the hygroscopic fibrous layers are replaced by thin-walled cells where dehiscence of the anther takes place by the contraction of the layers and the rupture of the wall.

Since the development of the pollen grain, as a single cell, many changes take place within it till it contains two sexual cells ready for fertilisation. At first, the single nucleus of the cell divides itself unequally into two. The

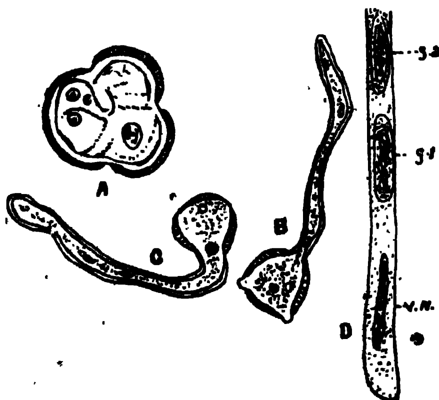


Fig. 226.

Developing pollen grain. A—A grain with a vegetative cell and two generative cells. B. C—Grains producing pollen tube. D—The tip of the pollen tube. VN—Vegetative nucleus. g.1, g.2—Two generative cells.

bigger nucleus called **vegetative nucleus**, is the nucleus of the main cell of the spore called **vegetative cell**. Round

the small nucleus protoplasm condenses and forms a naked cell. This nucleus, again, is divided into two, round which, as the result of condensation of protoplasm, two naked cells, called **generative cells**, are formed. The formation of two generative cells may occur before, or, in some cases after, the transference of the grain to the mature stigma. The generative cells or **male gametes** lie embedded in the protoplasm of the vegetative cell.

Macrospore and Female gamete.

We know that nucellus is the main body of the ovule. The nucellus consists of many parenchymatous cells, one of which in the middle becomes well-developed, differentiated and slightly curved. This developed cell is known as

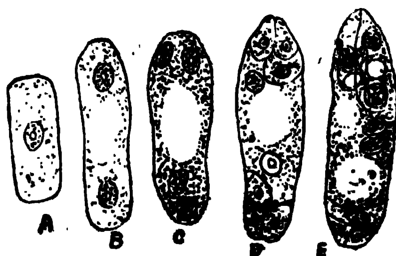


Fig. 227.

Developing embryo-sac. A—With a single nucleus. B—With two nuclei—one at the micropylar end and the other at the chalazal end. C—Two nuclei at each end. D—Four nuclei at each end. E—Egg-apparatus at the micropyle, antipodal cells at the other end and secondary nucleus in the middle.

embryo-sac or macrospore. To begin with, it is a mere cell containing protoplasm, vacuole and a single nucleus. As growth goes on, the nucleus starts with its karyokinetic

division. Two nuclei are formed—one goes to the micropylar end and the other to the chalazal end. Two more divisions of the nuclei occur at each end where four are formed. At this stage, one from each end travels towards the centre and the two meet forming the secondary nucleus of the embryo-sac. Thus three nuclei remain at each end. Round the three at the chalazal end, protoplasm collects and cell-walls are secreted. Thus, three walled cells are formed there, known as the **antipodal cells**. Round the three at the micropylar end, protoplasm simply condenses, so three naked cells are formed. The group of these three cells is known as **egg-apparatus**. Of these, two are smaller and are placed side by side above the third cell which becomes bigger and forms the female gamete or **egg cell** or **ovum** or **oosphere.** The smaller cells are known as **help cells** or **synergidae.** Thus, when the embryo-sac is ready for fertilisation it is filled with the above cells.

Fertilisation

When the mature pollen grain is carried to the surface of the stigma, the changes of the grain continue even after its transference. As the result of these changes, the wall of the grain becomes elongated forming a pollen-tube within which the vegetative nucleus and then the sexual cells enter. The nucleus becomes disorganised soon after its entrance. The sexual cells make their way in the tube during the course of its prolongation. By the greedy absorption of sugary secretion of the stigma the pollen-tube passes through the cells of the stigma and the style, and ultimately reaches the ovule. It then enters the ovule through the micropyle and comes upon the nucellus. It

bores through the nucellus by secreting a kind of ferment and meets the embryo-sac. The tube now bursts at its tip and the gametes come out. Here the leading male gamete is guided by the help cells to meet the ovum. The male cell unites with the female cell and fertilises it. (See fig. 102, page 145).

The second male gamete unites, in most cases, with the secondary nucleus of the embryo-sac. This process is known as **double fertilisation**. The direct result of this union is the formation of endosperm-nucleus which after repeated divisions and aggregation of protoplasm round the divided nuclei results in the formation of a tissue known as **endosperm**. This becomes laden with food for the use of the embryo during its development.

Formation of embryo

When fertilisation is over, the help-cells and the three antipodal cells vanish leaving the oospore to develop. The oospore at first divides into two cells—upper and lower. In consequence of repeated transverse divisions of the upper cell, a chain of cells called **suspensor** is formed. The lower cell forms a mass of eight cells called **octants** by means of three divisions which are at right angles to one another. The eight superficial cells cut off from the octants form the **dermatogen** of the embryo. The inner eight cells divide to form the **plerome** and the **periblem**. The last cell of the suspensor also takes a part in the formation of embryo. It forms the root-cap and root-tip of the embryo which gradually becomes differentiated into **plumule, radicle** and **cotyledons**.

In Dicot embryo, between the two lateral protuberances representing the two cotyledons, lies the growing point of the plumule. So the **plumule is terminal** and the **cotyledons are lateral**. But in Monocots, there is a single cotyledon **which becomes terminal. The plumule is lateral.** The suspensor, here, may be filamentous or massive.

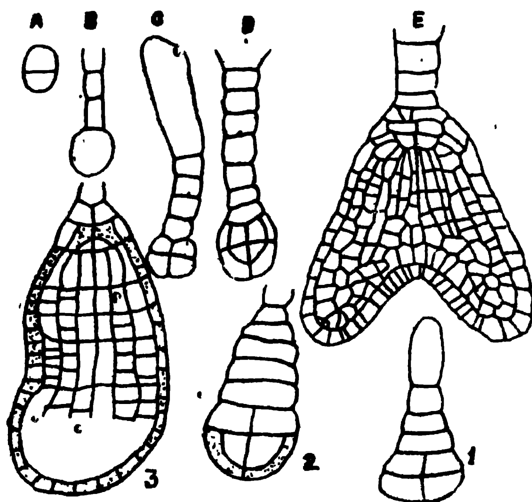


Fig. 228.

Development of oospore. A – Oospore divided into two cells. B – Suspensor formed. C—Suspensor and octants. D – Octants dividing. E – Embryo with two lobes as cotyledons, plumule between the lobes and radicle at the other end of the plumule. 1, 2, 3 – Developing stages of monocot embryo.

During the development of embryo it absorbs the whole of the surrounding tissue, nucellus. If the development is still incomplete, it absorbs endosperm. When the

absorption of endosperm is complete, the seed, formed from the embryo, is **exalbuminous**. But when a portion of endosperm persists after the development of embryo, the seed formed is **albuminous**. When the embryo develops into a seed with the partial absorption of nucellus, the portion of the nucellus remaining forms another nutritive tissue called **perisperm.** The perispermic seeds are found in *shaluk*, *kola*, etc. (consult the morphology of seed, page 170).

Alternation of generations

In tracing the alternation of generations of the plant,

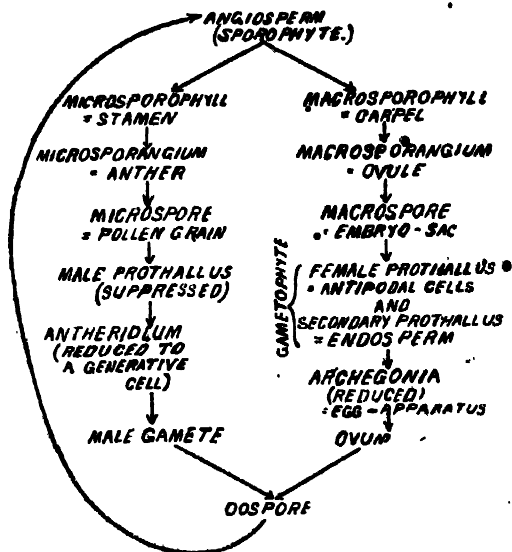


Fig. 229.

Graphic representation of the life-history of Angiosperm.

the body itself is found to be the sporophyte, as on it two

different types of spores develop. The microspores germinate on the macro-sporophyll i. e., the stigma, a part of the carpel. The gametophyte on the male side is greatly reduced to a generative cell while on the female side it is imperfect. Though the two kinds of sexual cells are distinct, the gametophytes on which they arise are much reduced or suppressed.

The three cells of the egg-apparatus are regarded as three reduced archegonia of which the synergidae have become abortive. The three antipodal cells correspond to the cells of rudimentary female prothallus while the endosperm tissue, formed after fertilisation, represents the secondary prothallus. On the male side, the cells of the grain correspond to all what are noticed in the stages of the male prothallus and the antheridium of Pteridophytes as Ferns.

The alternation of generations, as exhibited by the plants, is shown in the above table.

GYMNOSPERM

Gymnosperms form an intermediate group between the Angiosperms and vascular Cryptogams. In many respects they resemble the Angiosperms. They agree with them in the general histological structures, in the aggregation of the essential organs to form flowers and lastly in the production of seeds as the result of fertilisation. They differ mainly from the Angiosperms in their absence of ovary, style and stigma. Hence, the ovules formed remain naked. These naked-seeded plants are divided into three groups of which the most important one is that of the Conifers so called because their aggregated flowers form

cones. Plants belonging to this group are *Pines*, *Firs*, *Cedars*, *Junipers*, etc., most of which grow in the Himalayas.

Care should be taken that the common roadside *Jhau* plants, the branches of which, when gently swayed by the wind, give out a sound like that of the sea on a beach, is not a Gymnosperm but an Angiosperm.

Type—PINE

Morphology :—

This grows as a large tree in the hilly places. The plant bears two kinds of branches and leaves. The ordinary branches, growing indefinitely, are larger in forms. The only leaves borne on these branches are small scale-leaves. There are numerous other branches which are very small and limited in growth. They are called **dwarf shoots**. The leaves, developed on them, are green and acicular. At the base of those shoots scale leaves appear. The shoots arise from the axils of scale leaves of ordinary branches but no branches arise from the axils of green leaves.

Flowers are all unisexual. The calyx and corolla are totally wanting in them. The stamens and carpels only represent male and female flowers. Many stamens, aggregated together spirally on an axis, form the male inflorescence called **spike** developed at the base of the shoot of the present year. Similarly, many carpels form separate female inflorescence in the form of a **cone** situated at the apex of another shoot at the axil of scale leaves (monoecious).

A single male flower is a mere scale which bears only **two sessile pollen-sacs** forming the anther on its under-surface. The anther, when mature, bursts to discharge many minute, light and dry pollen grains, each having two wing-like expansions on its two sides. The grains are produced so abundantly, that during this time the plant



Fig. 230.

Pine. A—shoot B—Male flowers. C—Female flowers. D—Stamed E—Pollen grain. H—A scale of female cone. K—Ovuliferous scale with two ovules at the base.

seems to be covered by a mist. These grains are adaptive for wind pollination. Thus the male flowers of Pines differ from those of Angiosperms in having the stamens not differentiated into filament and anther and in having the anther two instead of four pollen-sacs.

Each female flower, borne on the cone, consists of two scales, one larger than the other. The large one, called **ovuliferous scale**, develops on the upper surface of the other small **bract-scale**. The large scale bears two ovules at the base on its upper surface. The bract-scale is regarded as the carpel which is not differentiated into ovary, style and stigma. The large scale is taken as the placenta developed on the carpel. After the fertilisation of the ovules, cone grows and gradually reaches maturity. In order to liberate the seeds, the scales of the cone separate from one another.

Sporophyte :—

As in Angiosperm, the plant-body is the sporophyte which bears two kinds of spores—pollen grain and embryo-sac cell. The wind-pollinated pollen grains are deposited directly on the nucellus. Thus, the pollination is direct. It does not take place through the intervention of style and stigma. Each ovule or macrosporangium has a single integument which surrounds the nucellus leaving the micropyle at the top. A large cell called **embryo-sac cell** is developed at the base of the nucellus.

Gametophyte

There being two kinds of spores, two forms of gametophyte are found to develop—one from the microspore and the other from the macrospore.

The changes in the unicellular pollen grain continue for two years after its transference to the surface of the

nucellus. As the result of the changes, several cells are formed in the grain of which two, at first cut off on one side, are called **prothallus cells. These represent the male gametophyte**, the equivalent of which is not so distinct in the Angiosperm. The remaining **antheridial cell**

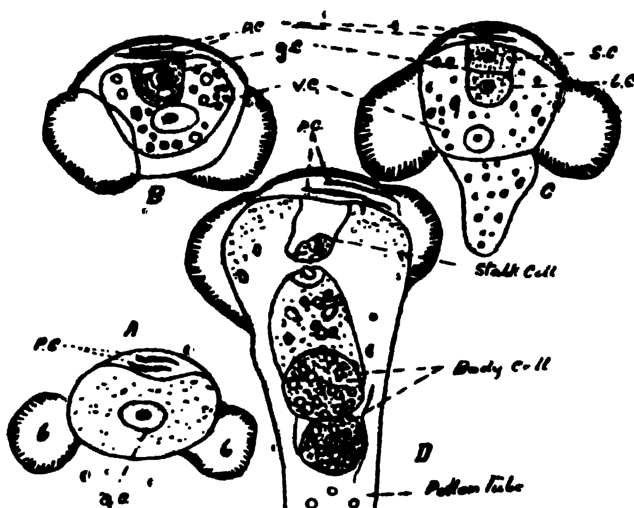


Fig. 231.
Developing pollen grain of Pine. A, B, C and D—Successive stages of development. PC—Prothallus cell. ac.—Antheridial cell. b—Ballon-like expansions of the grain. Gc—Generative cell. vc—Vegetative cell. Sc—Stalk-cell. bc - Body-cell.

divides unequally into a small **generative cell** and a large **vegetative cell**. In the second year, the generative cell dividing into two, forms a sterile **stalk-cell** and a dividing **body-cell**. This body-cell entering the pollen-tube soon gives rise to two male gametes only one of which is useful

in the act of fertilisation. The pollen-tube is very short as it is to bore its way only through the several cells of nucellus to reach the ovum when the gamete passes from the tube and fuses with the ovum.

The nucleus of the embryo-sac cell divides repeatedly and

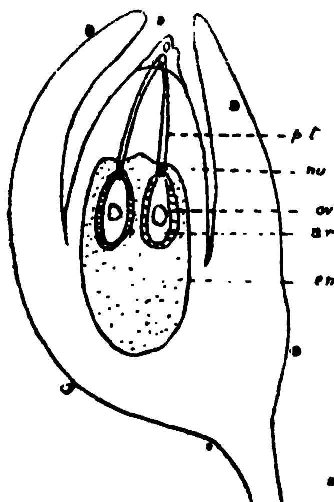


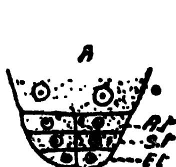
Fig. 232.
Ovule of Pine. Pt—Pollen tube. nu—Nucellus. ov—Ovule. ar—Archegonim. en—Endosperm.

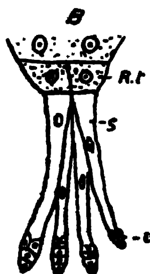
thus, by free cell-formation a parenchymatous tissue, called **endosperm,** is formed inside the sac. **This forms the female gametophyte or prothallus**. At its micropylar end, two or three groups of cells become differentiated. They are known as **archegonia** or female

organs. Each archegonium consists of a swollen portion called **venter** and a short **neck**. The venter contains a big naked cell called **ovum** or oosphere. One of the generative cells, coming out of the pollen-tube, fertilises the ovum and forms **oospore** as the result.

Formation of embryo

After several divisions of the oospore, four tiers, each consisting of four nuclei, are formed in the endosperm or prothallus. The lower three tiers, secreting cell-walls round each of the nuclei, form **rosette**, **suspensor** and **embryo tiers** in succession. Each of the four cells of the suspensor





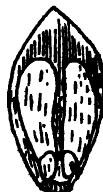


Fig. 233. Fig. 234.

A, B—Development of Pine embryo. Rt—Rosette tier. St—Suspensor tier. Et—Embryo tier. S—Suspensor. c—Embryo.

Fig. 234.—Pine seed.

tier elongates, and thus, four suspensors are formed, while the four terminal cells of the embryo tier give rise to four different embryos of which only one develops and the other three die off. The developed embryo consists of a **number of cotyledons** besides plumule and radicle.

There is **no endosperm formed after fertilisation.** The endosperm, formed before fertilisation, is not only the female prothallus but also a nutritive tissue,—the food materials of which are supplied to the embryo during its development.

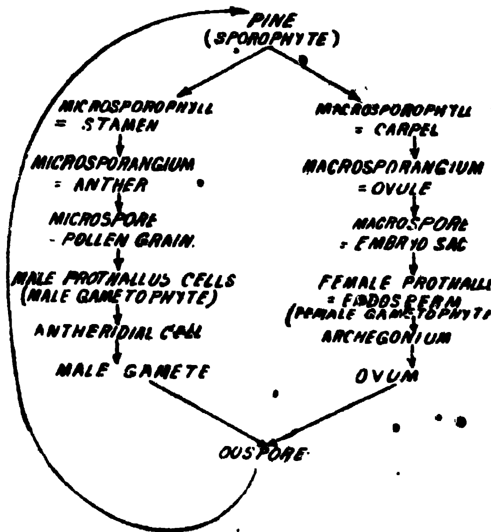


Fig. 235.

Graphic representation of the life history of Pine.

The alternations of generations is shown in the above table.

CYCADS

Cycad," another Gymnosperm, sometimes cultivated in Indian gardens is valued in China and Japan as its large pith yields a king of sago. Some species grow in Chittagong, Malay and Andaman Islands.



Fig. 236.

Cycad (Cycas revoluta). A—Plant. B—Carpel. o—Ovule. l—leaflet. C—Stamen. D—Germinating pollen grain. m—Ciliated spermatozoid. E—Developing seed. P—Pollen chamber. a—Archegonium. e—Endosperm. n—Nucellus.

Cycas revoluta, a Cycad, is cylindrical, unbranched, palm-like tree, bearing a terminal rosette of pinnate leaves which show circinate ptyxis like Fern leaves. There are two kinds of leaves in alternating zones on the stem. The small hairy scale leaves protect the large green foliage leaves.

The lower part of the stem is marked with the scars of fallen leaves. As in Leguminous plants, Cycad obtains nitrogen of the air through the help of certain Bacteria which form tubercles on its root.

The plant is dioecious and the flowers developed at the head are achlamydeous and in the forms of cones. The scales of the male cone, arranged spirally on the axis and corresponding to the single anthers of Dicot flowers, bear, on the under surface, many scattered pollen sacs or microsporangia arranged in clusters called **sori** like those of Ferns. The plant, thus, shows many fern-like characters. In each sorus, there are usually 3 to 6 sporangia. The carpels or macro-sporophylls, arising in clusters at the head, alternate with the foliage leaves. Each carpel is a pinnate leaf of which the lower leaflets are replaced by several large ovules.

The structures and development of pollen grains and ovules are much the same as in Pine. The following points of difference are specially noticeable.

(a) The two male gametes are moving cells called **spermatozoids**. They are provided with many **cilia** or whip-like bodies which help their movement.

(b) Each ovule has a stony middle layer in its fleshy integument.

(c) In the tip of the nucellus,a depression,called **pollen-chamber**, lying close to the head of endosperm or female prothallus, develops.

(d) The endosperm with the archegonia, formed at its apex, is contained within a wall.

(e) The pollen-tube bursts in front of the endosperm after penetrating only the nucellus, when the moving spermatozoids make their way to the archegonia.

Exercise II

1. What do you understand by 'alternation of generations'? Does this phenomenon occur among flowering plants?

2. Describe the processes which lead to the conversion of an ovule into a seed, and state what is the difference between albuminous and exalbuminous seeds.—C. U. 1927. 1918, 1910.

3. Describe the formation of the seed in a coniferous plant.—C. U. 1923.

4. Describe the life history of a fern, indicating briefly how it differs from that of a phanerogamous plant.—C. U. 1928.

5. In what respects does a fern differ from dicotyledon?—C. U. 1912.

6. Describe the sporophyll of any fern you have studied. In what respects do these differ from the stamens or carpels of the flowering plants?

7. Show, as concisely as possible, by reference to the morphological characters of a filamentous alga, a moss, a fern and a dicotyledonous plant, that you can observe in the vegetable kingdom, a gradual ascent in the complexity of structure.—C. U. 1925.

PART VI

CLASSIFICATION OF PLANTS

The object of classification :—

We see that there are many different forms of plants varying from microscopic unicellular organism to multi-cellular big trees, and the plants on the earth have different gradations of morphological and histological structures. Notwithstanding these variations, striking resemblances exist in the organs of some plants though there are differences in those of others. Botanists try to trace the close relationship between plants which are allied in their forms and structures and then to arrange them into separate groups, while they distinguish between those plants which are quite dissimilar. The main object of classification is to arrange plants according to their resemblances and differences in floral and vegetative characters and also to take notice of the affinities existing between the different groups of plants.

System of classification

There are two chief systems of classification :—(1) **Artificial** and (2) **Natural**.

Artificial system is founded on characters taken from certain parts of plants only without reference to others. It is purely an arbitrary method of classification which only

enables us to ascertain readily the name of a particular plant without helping us in any way to find out its geneological connection among the plants. The plants, here, are grouped according to a small number of their characteristics. The system, thus, insists much upon their differences but little upon their resemblances. Thus, according to this system *am, kool, dhutra, apang, karamcha, kalmi, hatisur, sagoon* are all placed side by side in one group (Pentandria Monogynia), simply because each of these plants has five stamens and one style. Similarly, *dhaniya, juan* are ranged by the side of *anantamul* because each of them has five stamens and two styles.

The grouping of plants in this system is similar to the arrangement of books in a library according to their different colours but not according to their subject matter. Owing to the defective arrangement the librarian finds himself in a fix if he has to find out several books of the same subject.

Among the several authors of this system **Linnaeus** was a prominent figure. On account of his great service, this is known as **Linnean system**. His classification was mainly based arbitrarily on the number and the mode of insertion of stamens and carpels. As his system did not satisfy the object of classification it soon lost many supporters.

Natural system takes into account all parts of plants and involves the idea of affinity in essential organs. It helps us in arranging plants according to their relationships and in detecting the position of plants in the system by short diagnostic marks. In doing so, a few essential characters are selected in accordance with natural affiinities.

Essential characters for classification :—

The grouping of plants depends upon some constant characters peculiar to them or to the groups to which they belong. Only those characters are useful for classification **which are less liable to modifications**. The characters of the reproductive organs are less liable to variations than those of vegetative organs. Of the vegetative characters, the venation, phyllotaxis and forms of leaves are usually taken into account. The reliable reproductive characters are—numerical strength of the floral members, cohesion, adhesion, symmetry, insertion of floral leaves on thalamus, placentation and structure of ovules.

Variety, species, genus, order, etc.

Species is a group of plants which resemble each other more closely than they do any other plant so that they are considered as originating from a common parent. The seeds of these plants produce always similar individuals. **Species, thus, is a group of plants which resemble one another in all important characters of their vegetative and reproductive organs.**

The characters which may vary, even in the same species, ought to depend on causes **exterior to the plant** and not in the plant itself. For example, its size, consistence and certain modifications of form and colour which we see change with the sun, climate and other influences are purely circumstantial. The species, with the varying

characters, may form one or several **Varieties. Varieties are, thus, the different types of one species which owe their origin to soil, heat, light, moisture and other conditions and have a constant tendency to revert to the original species from which they have come into existence.** Thus, mangoes, roses, paddies, cottons, etc. have a large number of varieties. All mango plants found anywhere on the earth form one species. But there are different types of mango plants producing fruits which differ in size, colour, taste, flavour, etc. They are the different varieties of the same species of mango. Similarly, there are different varieties of *dhan*, *gom*, *golap*, etc.

Several species are more nearly allied than others, and are conveniently grouped together to form a distinct **genus. Genus, thus, is an assemblage of nearly related species agreeing with one another more closely in their important reproductive characters than they do with other species.** The characters of a genus are taken more from the organs of reproduction than from other parts of plants. We know, all *sasha* plants are of one species. *Phuti*, *patal*, *makal* plants agree generally in their vegetative and reproductive characters but do not belong to one species as their seeds do not produce similar individuals. Though *sasha* and *phuti* plants differ in their vegetative structures, they resemble one another in the general structure and appearance of their reproductive organs; so these two species belong to one group or genus. Similarly *patal* and *makal* plants, belonging to two different species, are in one genus, as their reproductive organs agree in certain points, viz, in both, the petals are segmented at

their margins. *Sasha* and *phuti* have their petals with entire margins and are placed in one genus. But they form two distinct species owing to differences in the characters of fruits. Similarly *patal* and *makal* form two separate species as they differ mainly in respect of leaves, bracts and fruits.

Thus :—

(1) *Sasha* or Cucumis sativus, is under the genus **cucumis**.
Phuti or Cucumis Melo is also under the genus **cucumis**

(2) *Patal* or Trichosanthes dioica is under the genus **Trichosanthes.**
Makal or Trichosanthes palmata is also under the genus **Trichosanthes**.

A genus may contain a single species instead of a number of them, when the solitary species, constituting a genus, is characterised by marked peculiarities of the reproductive organs.

As each genus includes allied species, so several genera, agreeing more in general character, though differing in their special conformation, are grouped together to form a **Natural Order**. Natural Orders, thus, are groups of allied genera. So, when *shasa* and *shim* plants are compared, they differ widely regarding their vegetative and reproductive characters. But, when *shim* plants are compared with *chhola* plants, they agree in their general structures of flowers, fruits and seeds though they differ in minute details both in respect of vegetative and floral structures.

Natural Orders, having some important structural characters in common, are united together in groups, called **Sub-classes** which are again grouped into **Classes**. The Classes form **Sub-divisions** which are placed under **Divisions.**

The following table shows the different groups in respect of a particular plant, viz., *matar*, according to the system of Bentham and Hooker :—

Division—Phanerogamia.
Sub-division—Angiospermia.
Class—Dicotyledon.
Sub-class—Calyciflorae.
N. Order—Leguminosae.
Genus—Pisum.
Species—Sativum.
Varieties—*Kabuli matar*,
deshi matar.

The name of the plant thus is **Pisum sativum** (*matar*).

Bentham and Hooker's classification—

We have seen that the plant kingdom is grouped into two divisions :—(1) **Phanerogamia** and (2) **Cryptogamia**.

Phanerogams produce flowers and seeds. The seeds are many-celled bodies containing embryo by which the plants are reproduced. The seed-bearing habit is the most important character which distinguishes them from Cryptogams. The unicellular spores, produced by the latter are their means of reproduction.

The Phanerogams are divided into two groups :—(1) **Angiosperms** and (2) **Gymnosperms.** The former have their seeds always covered by fruits while the latter have no fruits ; so their seeds remain naked.

Angiosperms are further divided into two chief classes, (1) **Dicots** and (2) **Monocots**. We have noticed in Morphology how the two classes differ. Let us compare them and have the important morphological points of difference.

Dicot.	Monocot.
1. **Embryo** has two cotyledons.	1. **Embryo** has a single cotyledon.
2. Primary **root** persists and develops into a tap root.	2. Primary **root** does not persist and the roots are usually adventitious.
3. **Stems** have both axillary and terminal buds ; so they are much branched.	3. **Stems** have only terminal buds in most cases hence they are usually unbranched.
4. **Leaves** are reticulate-veined and may have stipules at their base ; leaves are numerous and usually small in size.	4. **Leaves** are mostly parallel-veined. Stipules are absent ; leaves are large in size with sheathing base and few in number.
5. **Flowers** are rarely trimerous, and are usually pentamerous.	5. **Flowers** are usually trimer-

Dicots are grouped into four sub-classes :—

(1) **Thalamiflorae** in which the flowers are complete, hypogynous ; the sepals and petals are usually free.

(2) **Calyciflorae** in which the flowers may be complete or incomplete, hypogynous, epigynous or perigynous ; the sepals are not free but petals are usually free.

(3) **Gamopetalae** in which the flowers are usually complete, bisexual, hypogynous or sometimes epigynous ; corolla is gamopetalous ; the stamens are epipetalous, usually not more than five ; the carpels are usually two in number and syncarpous.

(4) **Incompletetae** in which flowers may be monochlamydeous or achlamydeous, unisexual or bisexual.

Monocots are also divided into three sub-classes :—

(1) **Petaloideae** in which the perianth is petaloid.

(2) **Spadiciflorae** in which the flowers are in spadix.

(3) **Glumiferae** in which the perianth is absent or scaly, and there are glumes or modified bracts.

Nomenclature—

In naming a plant scientifically we generally use two words (binomial nomenclature). The first word represents the genus to which the plant belongs. This is the **generic name** of the plant. The last word for the specific name means the species to which the particular plant belongs. Thus, **oryza sativa** is the scientific name for *dhan*, in which **oryza** is the generic name and **sativa** is the name of the species. The name is never complete unless the two words are thus added together. Similarly, *banger chhata* is named **Agaricus campestris** and so on.

Floral formula :—

For representing the number of leaves, relative position, insertion, etc., of flowers in writing a floral formula, we usually use symbols or abbreviations. Thus, the following symbols are used against their names :—

Calyx = K ; Corolla = C ; Androecium = A ; Gynaecium = G ; Perianth = P ; Cohesion = ( ) ; Adhesion = ⌒ ; Superior Ovary = $\underline{G}$; Inferior ovary = $\overline{G}$; number indefinite = ∞ ; absent members = 0 ; members in two whorls = +.

Thus, for example, in order to represent a flower having four free sepals in two whorls, four free petals in one whorl, six free stamens of which two in one whorl and four in another whorl, two united carpels and superior ovary, we are to use the symbols in the formula in this way :—

$K_{2+2}\ C_4\ A_{2+4}\ G\ (\underline{2})$.

Floral Diagram

Diagrams are used in order to represent the arrangement and relation of the floral members in the different whorls. In these, the plan for the different positions occupied by the members is shown. Gynaecium occupies, usually, the central position. This is surrounded by stamens, then by petals and last by sepals. So, sepals occupy the external position. The superior and inferior positions of ovary can not be represented in diagrams.

The system of Bentham and Hooker compared with that of Engler.

In these days, prominence is given to two natural systems,—one of Bentham and Hooker and the other of Engler. The former is in use in British Dominions while the latter is largely followed in all other countries.

Engler has classified Dicots into only two sub-classes viz., (1) **Archichlamydeae** which corresponds to Thalamiflorae, Calyciflorae and Incompletae of Bentham and Hooker (2) **Matachlamydeae** or Sympetalae corresponding to Hooker's Gamopetalae.

Both the two sub-classes are divided into **Orders** which almost correspond to Cohorts of Bentham and Hooker. Each Order consists of **Families** corresponding to Natural Orders in Hooker's system.

All Monocots are grouped by Engler into four sub-classes, viz., (1) Glumiflorae (2) Spathiflorae (3) Liliflorae (corresponding to Petaloideae) (4) Microspermae.

DICOTYLEDONS

The system of classification, as devised by Bentham and Hooker, is shown in the following table.

Dicots

Thalamiflorae consists of the following important Natural Orders :—(1) Magnoliaceae (2) Anonaceae (3) Ranunculaceae (4) Nymphaeaceae (5) Papaveraceae (6) Cruciferae (7) Capparidaceae (8) Malvaceae (9) Sterculiaceae (10) Tiliaceae (11) Rhamnaceae (12) Vitaceae (13) Sapindaceae (14) Anacardiaceae (15) Rutaceae.

Calyciflorae consists of the following important Natural Orders :—(1) Leguminosae (2) Rosaceae (3) Myrtaceae (4) Umbelliferae (5) Cucurbitaceae.

Gamopetalae consists of the following important Natural Orders :—(1) Rubiaceae (2) Compositae (3) Apocynaceae (4) Asclepiadaceae (5) Solanaceae (6) Convolvulaceae (7) Verbenaceae (8) Acanthaceae (9) Scrophulariaceae (10) Boraginaceae (11) Labiatae.

Incompletae consists of the following important Natural Orders :—(1) Nyctaginaceae (2) Amarantaceae (3) Polygonaceae (4) Urticaceae (5) Euphorbiaceae.

Class—DICOTYLEDON

Sub-class—Thalamiflorae

N. O.—Magnoliaceae

Common plants of the family :—

(1) *Champa* (Michelia Champaca), (2) *Dulichampa* (3) *Magnolia grandiflora*.

Plants—trees or shrubs.



Fig. 237.
A—*Chpmpa* flower. B—Same showing many free stamens and carpels.

Leaves—simple, alternate, pinnately reticulate in venation. Stipules may be present, when present, they are large and enclose the leaf-buds but fall off when the leaves expand.

Flowers—Complete, hermaphrodite, regular, hypogynous.

Sepals—3, free, in one whorl. Petals—6 or more, 3 in each whorl, all free. Stamens—many, all free. Carpels—many, all free and arranged spirally on a convex thalamus.

Fruits—Aggregate of many follicles. Seeds—with albumen which is not ruminated or marked by wavy lines.

Floral formula—P_{3+6} $A\infty$ $G\infty$

N. O.—Anonaceae

Plants of the family :—(1) *Kantali champa*, (2) *Debdaru*, (3) *Ata* (Anona squamosa), (4) *Nona* or bullock's heart.

Plants—trees or shrubs, some are scramblers.

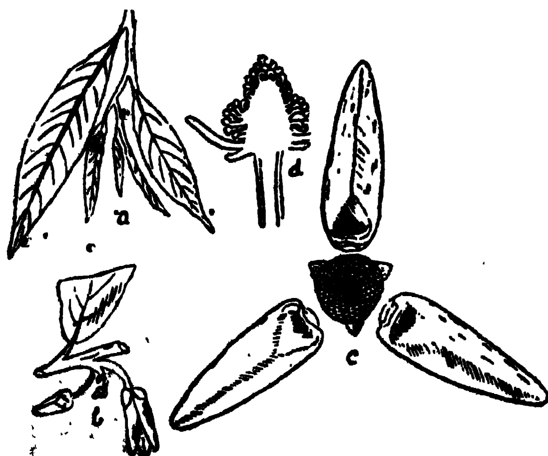


Fig. 238.

Ata. a—Branch. b—Floral shoot. c—Flower d—Stamens and carpels.

Leaves—Simple, arranged in two ranks on lateral branches, ex-stipulate.

Flowers—Complete, bisexual, regular, hypogynous. Perianth members valvate and of 3 or more whorls; three in each whorl, outer whorls are sepaloid and the inner whorls petaloid,—all free and spirally placed. Stamens—many, free, arranged spirally. Carpels—many and free. Ovary—superior with 1 ovule in each.

Fruits—Aggregate of berries. Seeds are ruminated.

This family is very closely allied to Magnoliaceae but differs mainly in having the albumen of seeds ruminated.

Kantali champa is a scrambler climbing by means of curved hooks (see fig. 42). *Ata* is a small tree. The carpels of the plant become united during development and form succulent fruits.

Floral formula—$P_{3+3+3}\ A\infty G\underline{\infty}$

N. O.—Ranunculaceae

Examples.—(1) *Chhagalbati* (Naravelia zeylanica), (2) *Kalajira.*

Plants are usually herbs. Leaves—Simple, compound or much divided, radical or cauline, usually alternate, ex-stipulate, though the sheathing petioles look like stipules. Flowers—complete, showy, regular, sometimes irregular. Sepals—5, free, imbricate. Petals—5, free, sometimes absent. Plants can be readily recognised, as in the above two families, by their numerous hypogynous stamens and their apocarpous pistil. Ovaries—superior, with one or many ovules in each ovary. Fruits—a number of achenes.

In *Kalajira*, the 5 carpels are not free. Seeds are used as spices. *Chhagalbati* is a climber. Its seeds are dispersed by wind.

Floral formula—$K_5\ C_5\ A\infty G\underline{\infty}$.

N. O.—Nymphaeaceae.

Common plants :—(1) *Padma* (2) *Shaluk.*

Plants—herbs, aquatic in habit.

Stems—Rhizome which sends down long adventitious roots into the soft mud. Leaves and flowers all rise from this underground stem.

Leaves—Simple, large, entire, peltate and floating with long petioles full of air chambers. The upper surface is

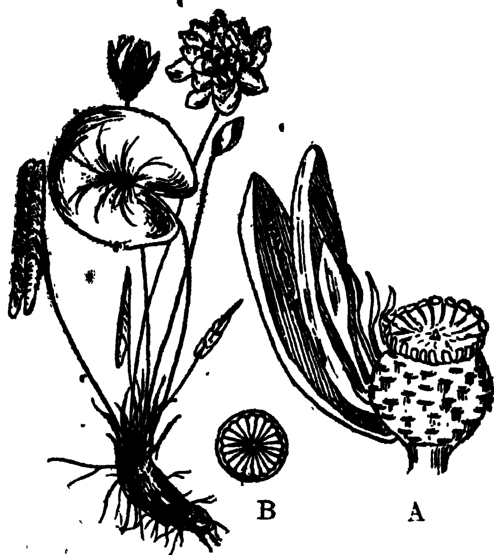


Fig. 239.

Shalook. A—Thalamus. B—Ovary section.

waxy, so when water falls on the surface, it runs off. Ptyxis is involute. Raphides, present in the leayes and other organs, protect the plants from the attacks of snails, slugs, etc.

Flowers—Floating, coloured red, white or blue, solitary, complete, hermaphrodite, large and showy. They are acyclic. Gradual transition occurs from sepals to petals and from petals to stamens. Stamens and carpels are many, free and spirally placed on the fleshy thalamus. Ovary—superior. Seeds have both endosperm and perisperm.

In *Shaluk*, the leaves are cordate in shape and serrate in their margin. Leaves and flowers float just on the surface of water. Sepals are four and green. Many carpels are united into a multilocular ovary over which radiating stigmas are placed. Fruits—spongy berries with many seeds.

In *Padma*, the leaf-stalks are prickly. The free carpels lie embedded singly in the cavities on the surface of a broad fleshy thalamus situated prominently in the centre of the flower. They form globular fruitlets aggregated together.

Propagation—Plants multiply by means of buds of rhizomes. Seeds are dispersed by water current. In *Padma*, the spongy thalamus helps the dispersion.

N. O.—Papaveraceae.

Examples :—(1) *Sheal kanta* (Argemone mexicana),—(2) *Poppy*.

Plants are annual herbs with latex. Leaves simple, alternate, exstipulate, pinnately lobed ; spinous in *Sealkanta*. Flowers—solitary, highly coloured, complete, regular, hypogynous. Sepals—2, free, caducous. Petals—4, free, in two whorls. Stamens—many, free. Carpels—2 to many, united. Ovary—unilocular with parietal placentas on which many ovules develop. Fruit—capsule, dehiscing by pores and containing many albuminous oily seeds.

Uses :—The opium is derived from the milky juice of the unripe fruit of *Poppy* plants. The seeds of the capsule (posto) are nutritious. The oil obtained from *Sheal kanta* seeds has medicinal properties.

Floral formula :—$K_2\ C_4\ A\infty\ G\ (\underline{2-\infty})$.



Fig. 240.

Poppy. a—Leafy shoot. b—Flower bud. c—Ovary. d—Fruit. e, f—Longitudinal and transverse sections of ovary. g—Seed. h—Floral diagram.

N. O.—Cruciferae

Common plants :—(1) *Sarisha* (Brassica Napus), (2) *Shwet Sarisha,* (3) *Mula* (Raphanus sativus), (4) *Kopi* or cauliflower and cabbage (5) *Shalgum* or turnip, (6) *Olkopi.*

Chief characters :—Herbs with simple, alternate and exstipulate leaves. Flowers are regular and bisexual with 4 petals arranged crosswise. Stamens—six and tetradynamous. Ovary—superior and formed of two carpels. Fruit —siliqua.

Type—*Sarisha.*

Plant—It is an annual herb with pungent juice. It flowers in winter. The soft and round stem branches racemosely.

Leaves are different in the different regions of the plant. The lower leaves are larger, stalked and lyrate but the



Fig. 241.

A—*Sharisha* plant with stem, leaves and flowers. B—Fruit.

upper leaves are smaller, sessile and lanceolate in shape. The leaves are all simple, alternate, and exstipulate.

Flowers—The yellow flowers arranged in racemes are hypogynous, dimerous and ebracteate. Sepals—4, free and in two whorls, two in each whorl. Petals—four, free, in one whorl and in the form of a cross (**cruciform**) from which the name of the family is derived. Stamens—6, free, of which 4 are longer than the other two (**tetradynamous**). The four stamens in two pairs are in one whorl, while the other two, in another whorl, alternate with the pairs. There is honey at the base of short stamens. Carpels—two, united to form a syncarpous, superior ovary. Stigma—round and capitate on a short style. The ovary is at first unilocular, with two parietal placentas but gradually it becomes bilocular when the placentas meet to form a false replum.

Fruit—simple, dry, and a **siliqua**. When it dehisces, it splits from the base into two valves, while the numerous seeds remain attached to the persistent replum. Seeds contain fatty oil which serves as a food for the young seedling. A thin layer of endosperm being present, the seeds are not ex-albuminous.

Pollination is effected by the insects allured by the colouration of flowers and the presence of honey. Flowers are protogynous, so stigma matures before the stamens. The shorter stamens ripen first, and insects carry their pollen, but when the latter fail to visit the flowers, the stamens elongate to reach the level of the stigma which is then pollinated.

Floral formula :—K_{2+2} C_4 A_{4+2} $G\,(\underline{2})$

Other plants of the family.

Mula is another annual herb possessing swollen edible roots. Flowers are white. *Cauliflower* has all the

parts of the inflorescence highly fleshy. In the same way, the leaves of *Banda-kopi* are more or less fleshy and nutritious. They are used as vegetables.

Uses :—Some plants have seeds which yield oil, others have seeds used as spices. Many of them are used as vegetables owing to the fact that in different plants some portions swell out by cultivation. Most of the plants grow in winter.

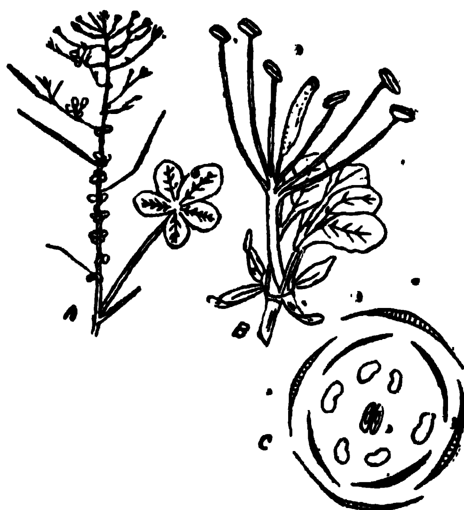


Fig. 242.
A —*Hurhurhe* plant. B—Flower. C—Floral diagram.

N. O.—Capparidaceae.

Examples :—(1) *Shada Hurhurhe*, (2) *Halde Hurhurhe*, (3) *Barun* (4) *Kantagur-kamai*.

Plants—Herbs, sometimes climbing. Leaves—simple or palmately compound, alternate and stipulate. Flowers—in racemes or corymbs,

complete, hypogynous, usually irregular. Sepals—4, usually free and in one whorl. Petals—4, free, in one whorl. Stamens—4 or 6, all free and of equal length. Carpels—2, united. Ovary—superior, usually seated on a gynophore ; unilocular with 2 parietal placentas arising on the replum. Fruits—same as in Cruciferae to which this Family is closely related.

It differs mainly from the plants of Cruciferae, in possessing stamens which are not tetradynamous and in having no cruciform corolla.

Floral formula :—K_4 C_4 A_6 G $(\underline{2})$

N. O.—Malvaceae.

Common plants—(1) *Jabà* (Hibiscus Rosa-sinensis) (2) *Kapas* (Gossypium herbaceum), (3) *Shimul* (Bombax malabaricum), (4) *Sthalpadma*, (5) *Dhanras*, (6) *Berela* (7) *Petari* (8) *Mestapat* or *Madras hemp*.

Chief characters—Herbs, shrubs or trees often with mucilage. Leaves—stipulate and palmate. Flowers—showy, regular, hypogynous and pentamerous, mostly with epicalyx. Stamens—monadelphous. Ovary—syncarpous and multilocular.

Type—*Kapas* or **cotton plant**.

There are several varieties of cotton cultivated in India. Plant is a bushy perennial shrub with erect branched stem. Branches are racemose but sometimes sympodial. Leaves—simple, alternate and with free lateral stipules found specially in the young leaves. The venation is palmately reticulate. Leaves are also palmatipartite and segmented into 5 or 7 lobes.

Flowers are yellow coloured, large, complete and bracteate. The three large serrated bracts, forming an

epicalyx just below the flowers protect them when they are in the buds. The bracts persist even after the formation of fruits. Calyx is cup-like and gamosepalous consisting of 5 teeth-like sepals. The five petals are all free but slightly united at the base with the stamens. The aestivation of the petals is twisted. There are numerous stamens—the filaments of which are all united to form a hollow tube through which the long style passes. From the upper region of the tube, many short branches arise, each terminating in a reniform and unilocular anther. The five free stigmas are at the end of the style. The ovary is superior and 5-celled with axile placentation.



Fig. 243.
Kapas plant with flower and fruit.

Fruit is simple, dry and a capsule—dehiscing into 3 to 5 valves which liberate many fibrous seeds. These fibres called **cotton** help the dispersion of seeds by wind to a great distance. The seeds contain an oil which is nourishing to the cattle.

Pollination is effected by insects which are attracted by the coloured petals or by the pollen grains, most of which

are for the food of the pollinating insects. Flowers are protandrous ; when cross-pollination fails, self-pollination takes place by the curling back of the stigmatic heads to receive the mature grains placed below.

Floral formula—$K_{(5)}\ C_5\ \underline{A_{(\infty)}}\ G_{(\underline{5-\infty})}$

Some other plants of the Family :—

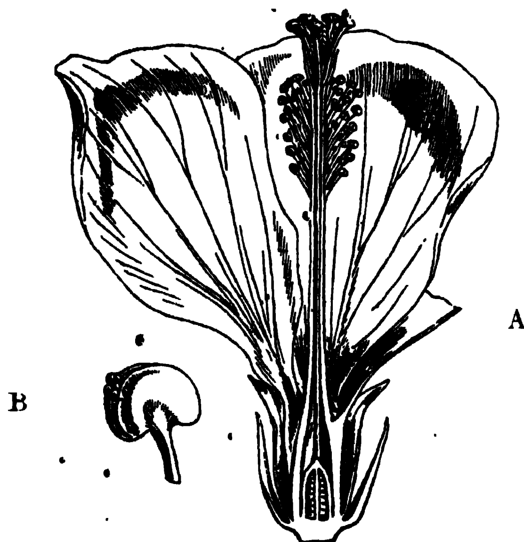


Fig. 244.
A—Longitudinal section of *jaba* flower. B—Kidney-shaped anther of *jaba*.

1. *Jaba*—Leaves are ovate in shape and serrate in margins. Bracts are 5 to 10 in number. Sepals are united to a gamosepalous calyx. Anther—kidney-shaped. The ovary is pentalocular. The seeds are not hairy.

2. *Simul*—This is a tree bearing compound leaves. The large red flowers attract many birds which pollinate them. Epicalyx is absent. Stamens, forming separate groups above, appear to be polyadelphous but really they are monadelphous.

Uses :—Different varieties of *Kapas* are economically important, as calico is manufactured from the hairs of the seeds. The stems of the plant yield a good fibre. The seeds are used as fodder. Given to milch cows, it increases the flow of milk. Seeds also contain an oil. The fibres of the seeds of *Shimul* are important for stuffing cotton and soft packing woods. The bast fibres of *Mestapat* are strong enough to make hemp. The plants like *Berela, Bonokra* are medicinal. The fruits of *Dhanras* are used for vegetable curries. *Sthalpadma* is an important garden plant cultivated for showy flowers.

N. O.—Sterculiaceae.

Examples (1) *Ulat Kambal* (Abroma augusta) (2) *Moochkunda* (3) *Sundri* (4) *Jangli badam*.

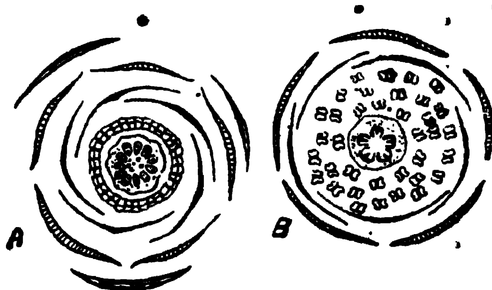


Fig. 245.
A —Floral diagram of Malvaceae. B—Floral diagram of Sterculiaceae.

This is very closely allied to Malvaceae and Tiliaceae.

Plants—Trees, shrubs or herbs. Leaves—simple, alternate, stipulate, palmately veined. Flowers—complete, regular, hypogynous, sometimes unisexual. Sepals—5, united, valvate. Petals—5, free or attached to the stamens, sometimes absent. Stamens—monadelphous or sometimes free, anthers are two-celled. Carpels—2 to 5, united or free. Ovary—superior, 2-5 chambered with many ovules. Fruits—fleshy or dry which may dehisce.

Floral formula—$K_{(5)}\ \overline{C_5\ A_{(\infty)}}\ \underline{G}_{(2-5)}$

N. O.—Tiliaceae.

Examples :—(1) *Pat* (Corchorus capsularis), (2) *Rudraksha*, (3) *Phalsa*.



Fig. 246.

Pat. a—Shoot. b—Flower. c—Ovary. d—Friut. e—Fruit dehiscing. f—Seed. g—Floral diagram. h—Anther.

This is also very closely related to Malvaceae and Sterculiaceae. This order along with Sterculiaceae differ from Malvaceae mainly in possessing two-celled anthers.

Plants—trees or shrubs with the inner bark fibrous. Leaves, sepals and petals agree with those of Malvaceae. Inflorescence—cymose. Stamens—many, free or polyadelphous, inserted on a disc, anthers are two-celled. Carpels and fruits are like those of Sterculiaceae.

Uses :—The tough fibres of the bark of *pat* are used to make gunny bags.

N. O.—Rhamnaceae.

Common plants :—(1) *Kul* (2) *Sheakul*.

General characters—Plants are thorny strugglers. Leaves are simple with spinous stipules. Flowers - small and in cymes. They are regular, unisexual, bisexual or polygamous. Sepals on a disc are



Fig. 247.

Kul. a—Leaf. b—Flower. c—Longitudinal section of flower. d—Floral diagram.

united. Petals—five, spoon-shaped. Stamens—five and opposite to the etals. Ovary—3-or 4-celled and nearly inferior. Fruit—drupe.

N. O.—Ampelideae or Vitaceae.

Examples :— (1) *Harjorha* (2) *Angur* or vine, (3) *Goale lata.*

Plants are usually climbers, climbing by means of tendrils which are modified branches, though placed on the opposite sides of leaves. Stems—jointed, sometimes angular. with sympodial branches (see page 50). Leaves—alternate, stipulate, simple or 3 to many



Fig. 248.

Angur A—Shoot. B—Flower showing 5 stamens and ovary. C—Flower showing the expanding petals.

foliate palmately compound. Inflorescence—cymose. Flowers—minute, greenish, complete, sometimes unisexual, hypogynous. Sepals—4 or 5, minute, united. Petals—4 or 5, cohering at their apices ; they are thrown off as a cap by the expanding stamens which are 4 or 5, all free, introrse. Carpels-2, united. Ovary—superior, 2 to 6 chambered, seated on a prominent disc. Ovules—2 in each chamber. Fruit—berry with albuminous seeds.

Uses :—We owe raisin, grapes to this family.

Floral formula—$K_{(5)}\ C_5\ A_5\ G_{(\underline{2})}$

N. O.—Sapindaceae.

Examples :—*Lichoo* (Nephelium Litchi), (2) *Ansphal*, (3) *Ritha* (4) *Shibjhul.*

Plants are usually trees or shrubs, sometimes climbing by tendrils. Leaves usually pinnately or palmately compound, alternate, exstipulate. There are terminal and axillary panicles of many small, polygamous, regular or irregular flowers. Sepals 4 to 5, free or

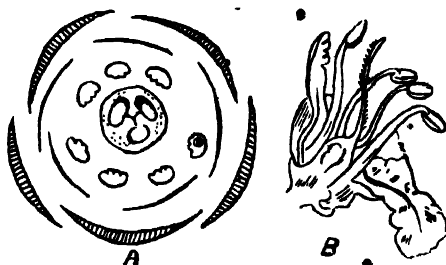


Fig. 249.
Lichoo. A—Floral diagram. B—Flower.

uuited, inferior. Petals—4 or 5, but in *Lichoo* they are absent. Stamens—5 to 10, all free. Carpels—2 to 3, united. Ovary—trilocular, superior, inserted on an oblique disc. Fruit—dry or fleshy with usually an arillated seed.

N. O. –Anacardiaceae.

Common plants—(1) *Am* or mango (Magnifera indica), (2) *Amrah*, (3) *Hijlibadam*, (4) *Jiuli.*

General characters :—Plants are trees or shrubs with acid or resinous juice. Leaves—simple or compound, exstipulate. The small flowers arise in panicles. They

are unisexual, bisexual or polygamous, regular. The disc is ring-like. The sepals, petals and stamens are all 4 to 5. Carpels—two and united. Ovary—superior, one-celled containing only one ovule. Fruit— a drupe.



Fig. 250.
Am (Mango). A—Flower. B—Fruit. C—Section of the fruit.

N. O.—Rutaceae.

Common plants—(1) *Kamla nebu*, (2) *Nebu*, (3) *Batabi-nebu*, (4) *Gora nebu*, (5) *Bel*, (6) *Kath-bel*, (7) *Kamini* (8) *Ush-khaora*.

General characters :—The plants are usually trees or shrubs. Leaves usually compound. In different kinds of

Nebu, the leaves are articulated between the blade and the winged petiole indicating that they are of unifoliate compound type. Leaves and other organs have glands with ethereal oil,—easily seen when held up against light. Flowers are complete, regular and hypogynous. Sepals—4 or 5, united, Petals—4 or 5, free and valvate. Stamens

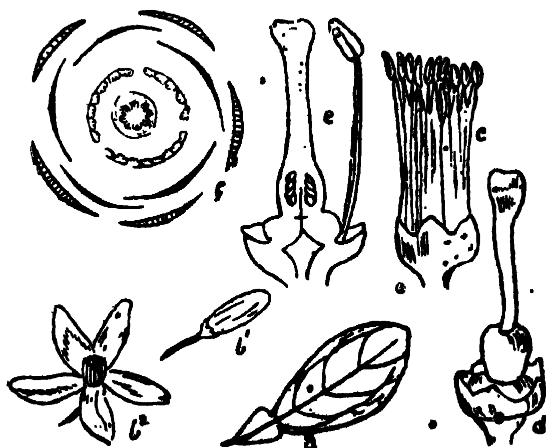


Fig. 251.
Batabinebu. a—Leaf. b¹—Flower bud. b²—Flower. c—Androecium. d—Ovary. e—Longitudinal section of ovary. f—Floral diagram.

—4 to many, free or polyadelphous. There is a distinct disc on which the ovary is placed. Style and stigma are simple. Fruit may be drupe, berry, hesperidium or capsule. Seeds are very few in each chamber.

Floral formula—$K(4-5)\ C4-5\ A\infty\ G(\underline{\infty})$

N. O.—Leguminosae.

Chief characters—Herbs, shrubs or trees. Leaves—usually compound (simple in *Atushi*), alternate and stipulate. Flowers—zygomorphic or regular. Sepals—5. Petals—5. Stamens—ten or many, free or combined. Carpel—one, ovary superior, one chambered. Fruit—legume or lomentum,

This is one of the largest families. This is divided into three sub-orders—(a) Papilionaceae (b) Caesalpinieae (c) Mimoseae. The sub-orders agree closely in their sepals, carpels and leaves differing only in respect of petals and stamens.

(a) Sub-order—Papilionaceae.

Common plants—All pulses as (1) *Matar* or pea (Pisum sativum) (2) *Chhola or* gram (3) *Arahar* (4) *Masur* (5) *Sonamoog* (6) *Mash kalai etc.*; (7) *Barbati* (8) *Shim* (9) *Chiner badam* (10) *Shankaloo* (11) *Bak* (12) *Aparajita* (13) *Palas* (14) *Kooch* (15) *Nil* (16) *Shola* (17) *Palte-madar* (18) *Sishu* (19) *Atushi.*

Type—*Matar* or **pea.**

The plant is an annual herb and creeper, The leaves are compound, pinnate, imparipinnate and alternate. The upper leaflets are modified into branched tendrils which help the plants in catching hold of supports. At the base of the petiole there is a large foliaceous stipule which also performs the functions of leaves (see fig. 64). Towards the end of the day leaflets fold in pairs and show sleep move-

ments. Roots are with tubercles in which certain Bacteria grow symbiotically (see page 314).

Flowers are in simple racemes. They are complete, irregular, zygomorphic and perigynous. The calyx is gamosepalous and bilabiate. The corolla is papilionaceous. The largest of the 5 petals called, **standard** encloses two side-petals called **wings** which again enclose the remaining

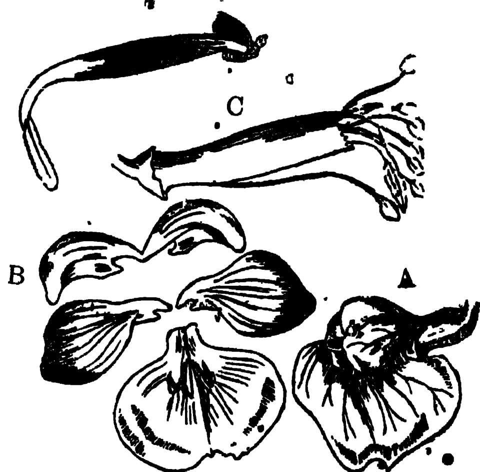


Fig. 252.

Matar Flower. A—Flower. B—Petals. C—Stamens. D—Carpel.

two called **keel** or **carina**. The aestivation is thus vexillary. The keel again encloses the 10 stamens, 9 filaments of which are united into one bundle and one remains free; the anthers are all free **(diadelphous)**. The ovary of the single carpel is elongated and with marginal placentation. The style is short and the stigma is brush-like. The ovules are on the ventral suture.

The fruit is simple and dry, a legume or pod. It bursts through both the sutures to liberate the seeds. The exalbuminous seeds have two large fleshy, hypogeal cotyledons.

Pollination is effected by insects which try to get at the honey present within the tube of the filaments and in their attempts they are to press down the keel when the style protrudes and touches the body of the insects. If an insect comes after the visit of another flower where its hairy body was covered with pollen it is sure to pollinate the stigma.

Some **other plants** of the sub-order :—*Musur chana* or *Janglimater* has all the leaves, converted into tendrils. *Aparajita* is a twiner. The stamens here are monadelphous or diadelphous, sometimes free. The plants of *Bak*, *Palash*, *Madar* and *Sishoo* are all trees in which the tendrils are absent. The flowers of *Chiner-badam* grow within the soil due to the twisting of their elongated peduncles. The fruits also grow and ripen beneath the soil. *Shankaloo* has edible tuberous roots.

Floral formula— K(5) C5 A(9)+1G1

(b) Sub-order—Caesalpinieae.

Common plants :—(1) *Kalkasunda* (Cassia sophera) (2) *Krishna chura* (3) *Radha chura* (4) *Asoka* (6) *Kanchan* (6) *Tentul* (7) *Nata*.

Type—*Kalkasunda*.

The plant is a small bushy shrub. It is a common weed of Bengal. Leaves are paripinnate and glands are

in the place of stipules. There are stipels at the base of the leaflets.

Flowers appearing in racemes are not so irregular as the papilionaceous flowers. Petals are imbricate in bud. The innermost petal is inside the lateral ones. Stamens are 10, all free. Some are perfect, while others are sterile. Carpel—same as in pea.

Some **other plants** of the sub-order :—Most of the plants agree with those of papilionaceous plants. The main

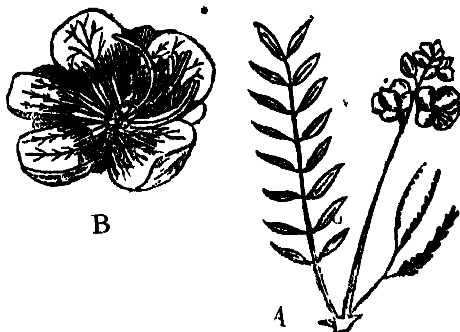


Fig. 253.
Kalkasunda A- Floral shoot. B—Flower.

points of difference lie in the structures of corolla and cohesion of stamens.

Tentul is a big tree with three free petals (the other two reduced to scales) and three perfect stamens in the flower. The fruits are constricted legumes full of acid pulp. In *Kanchan*, the two leaf-lets are usually joined together to form one leaf. In some species of *Kanchan*

(Bauhinia diphylla), the two leaf-lets are separate. *Asoke* has its petals absent but the calyx is 4-lobed and petaloid; bracteoles are coloured and persistent. *Radhachura* or *Bara krishnachura* or gold mohar tree generally planted



Fig. 254.
Tentul. A—Shoot B—Fruit.

on the roadside produces in the month of April many large red flowers which are pollinated by birds.

Floral formula—$K_{(5)}$ C_5 A_{10} $G\underline{1}$

(c) Sub-order—Mimoseae.

Common plants—(1) *Babla* (Acacia arabica) (2). *Lajjabati* (Mimosa pudica) (3) *Sirish* (4) *Khair*.

Type—*Babla*.

The plant is a prickly tree with tannin in the bark. Leaves are bipinnate. The stipules are modified into thorns. Stems exude gum which has commercial value.

Flowers are very small and clustered recemosely. Within the cup of the calyx four or five yellow petals arise.

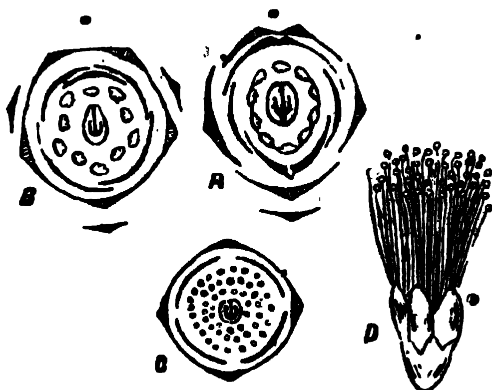


Fig. 255.
Floral diagrams. A—Papilionaceae. B—Caesalpinieae C—Mimoseae. D—Flower of *Babla*.

which are valvate in bud. The stamens are numerous and free. The fruit is a constricted lomentum which dehisces transversely.

Some **other plants**:—*Lajjabati* leaves are so sensitive that on the slightest contact the leaflets droop. Sepals and

petals are four. *Sirish* is a roadside tree bearing bluish flowers. The stamens are monadelphous.

Floral formnla $K_{(5)}\ C_5\ A\infty\ G\underline{1}$

The following table shows the points of difference among the three sub-orders.

	Sub-order	Inflorescence	Flower	Aestivation	Stamens	Fruit
1	Papilionaceae	Raceme	**Papilionaceous and zygomorphic**	**Vexillary**	**10, diadelphous**	Legume
2	Caesalpinieae	"	**Slightly irregular**	**Imbricate**	**Usually 10, all free**	Legume or Lomentum
3	Mimoseae	Racemes, Spike or Capitate	**Regular**	**Valvate**	**8, 10 or indefinite, mostly free**	Lomentum

Uses—The nutritious cotyledons of the seeds of all pulses, *Shim*, *Barbati*, etc., form important Indian dishes. The woody stems of *Sishoo*, *Chandan*, *Babla*, etc., furnish valuable timber. *Nil* and other plants yield dyes as log-wood and indigo. *Babla*, *Khair*, *Asoke* etc., are noted for the astringent properties of their bark. *Sirish*, *Babla* are also important for their gum or commercial value. From some plants as *Asoke*, *Tentul*, etc., medicines are derived. The seeds of *Koonch* are used as weights by gold-smiths. *Shone* yields fibres.

N. O.—Rosaceae

Examples (1) *Golap* (2) *Peach* (3) *Apple* (4) *Alu bokra* (5) *Loquat.* (6) *Nashpati.*

Plants include trees, prickly scramblers and herbs. Leaves—simple or compound pinnate, alternate and usually with adnate stipules.

Flowers—complete, regular, perigynous. Sepals—5, united, inferior. Petals - 5, all free, imbricate. Stamens—many, all free. Carpels—1 or several, apocarpous, Each carpel contains a single ovule. Fruit—aggregate, drupes, pomes or achenes. Seeds—exalbuminous.

This order is allied to Leguminosae with which it agrees specially in having perigynous flowers. In India, the whole family is confined to the hills.

Uses—The whole family is characterised by the prevalence of fleshy, edible fruits and the beauty and fragrance of the flowers. The well-



Fig. 256.

Golap growing in the hills. a—Floral shoot. b—Longitudinal section of flower. c—Carpel. d—Fruit. e, f—Seed. h—Floral diagram.

known fruits of apple, cherry, peach, loquat, pear are all grown in the hills and some of them are natives of the Himalayas and Kashmere.

The wild rose has five petals only but the number has enormously increased by cultivation.

Floral formula—$K_{(5)}\ C_5\ A_\infty\ G\ \underline{1-\infty}$.

N. O.—Myrtaceae.

Common plants :—(1) *Peyara* or guava (2) *Jam* (3) *Galap jam* (4) *Jamrool* (5) *Hijal* (6) *Labanga* (7) *Eucalyptus.*

General characters—Plants are usually trees or shrubs. The leaves are simple, opposite, exstipulate and with pellucid dots. Each dot is an oil gland. There is a vein running just within the margins. Sepals 4 or 5, united.



Fig. 257.
Peyara. A—Floral shoot. B—Section of a flower.

Petals 4 or 5, free. Stamens are numerous and free or polyadelphous. Ovary—inferior, usually 1—celled with parietal placentation. Fruit—mostly berry.

N. O.—Umbelliferae.

Examples :—(1) *Dhania* (2) *Mouri* (3) *Juan* (4) *Shulpa* (5) *Radhuni* (6) *Jeera* (7) *Thulkuri* (8) *Gajor* (9) *Hing.*

Plants are mostly annual herbs with aromatic odour. Stems—hollow, erect, ribbed and green. Leaves—large,

much-divided, often decompound, alternate, always with sheathing petioles but with no stipules ; sometimes simple as in *Thulkuri*.

Inflorescence consists of compound unbels with general and partial involucres. Flowers—small, complete, bracteate, actinomorphic but the outer flowers of the umbel are

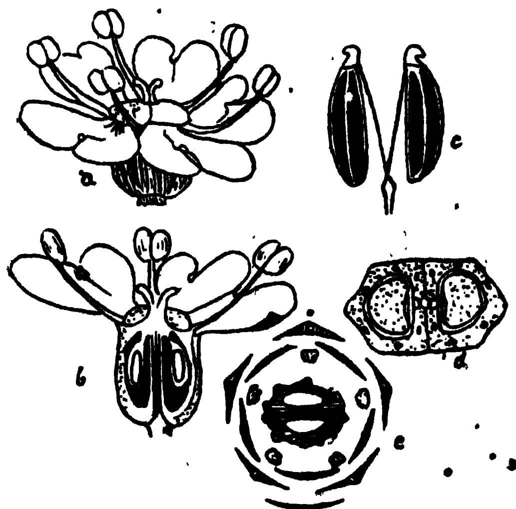


Fig. 258.

Flower of *Dhania*. a—Flower. b—Section of the same. c—Fruit. d—Section of the fruit. e—Floral diagram.

zygomorphic as their outer petals are larger than the inner. Sepals—5, lobed, united, superior. Petals—5, free, superior, usually white, with inflexed tips. Stamens—5, free, with filaments curved inwards. Carpels—2, united. Ovary—inferior, two-celled, with one ovule in each cell, crowned by a disk. Styles—2. Fruit—a cremocarp consisting of 2 dry mericarps which separate when ripe but remain attached to a

common axis called carpophore. There are 5 long ridges with oil canals on the walls of the fruit. Seeds—2, albuminous.

Uses—Most of the plants are cultivated for their fruits which are generally used as spices. The soft weak plants are protected from the attacks of grazing animals by the peculiar odour of their stems and leaves.

Floral formula—$K_5 C_5 A_5 \overline{G}_{\dot{2}}$

N. O.—Cucurbitaceae.

Common plants (1) *Shasha* (Cucumis sativus) (2) *Mitha-kumra* (Cucurbita maxima) (3) *Lau* (4) *Chalkumra* (5) *Phuti* (6) *Tarmuz* (7) *Telakucha* (8) *Karala* (9) *Chichinga* (10) *Patol* (11) *Jhinga* (12) *Kakrole.* (13) *Dhundul.*

Chief characters—Plants are all tendril-climbers. Leaves—simple, cordate and palmiveined. Flowers—unisexual,



Fig. 259.
Male and female flowers of *Kumra.*

usually monoecious. Stamens have sinous anthers. Ovary—inferior with parietal placentation. Fruit—mostly pepo.

Type—*Shasha* or cucumber

The plant is a climber climbing by means of tendrils which arise from the base of leaves. The tendrils are highly sensitive.

Roots are normal but when the stems grow on moist soil, white adventitious roots also develop from the nodes.



Fig. 260.
Shasha—floral shoot.

Stems are soft, hollow and with five ridges. Many bristly hairs cover the surface of stems and leaves. The upper internodes are very long and twisted. At the nodes there are leaves, leaf-buds, tendrils and flower-buds in addition to the roots, if present. Leaves are simple, alternate, large, palmately reticulate veined, cordate and lobed.

Flowers arise singly or in small clusters from the axils of leaves. They are incomplete, unisexual and regular. The

male and female flowers are on the same plant (monoecious). Sepals are united at their base. Five petals are also united to form a bell. Stamens are only in the male flowers. They are epipetalous and five, of which four are united into two and one remains free. Anthers are long and wavy. Gynecium in the female flowers consists of three carpels united to form a syncarpous, inferior ovary with a short style and three stigmas. The united margins of the carpels project inwards and then turn outwards so that the placentation is parietal. The numerous ovules arise from the hooked ends of the placentas. Fruit—simple, berry or pepo with many exalbuminous seeds.

Pollination—Flowers being unisexual, cross-pollination takes place by the aid of flies or ants which are attracted by the nectar at the base of corolla. The pollinating agents carry pollen from the large male flowers to which they usually pay their first visits. There is no chance of self-pollination.

Floral formula—

For male flowers :—K(5) C5 or (5) A(2) + (2) + 1,

For male flowers :—K(5) C5 or (5) $\overline{G(3)}$

Other plants—*Patol* is dioecious. Though the Order belongs to the Sub-class Polypetaleae, corolla of some plants as *Lau*, *Chalkumra* is gamopetalous.

Uses—Most of the plants are used as vegetables. They are valued for their succulent fruits. The red berries of *Telakucha*, *Makal* are greedily devoured by birds by which the seeds are dispersed. In *Dhundul*, the seeds are thrown away due to the extreme turgidity of ripe fruits.

N.O.—Passifloraceae.

Examples—(1) *Jhumkolata* or Passion flower (2) *Pampe* (Carica papaya).

This is very closely related to Cucurbitaceae from which it differs in possessing bisexual flowers with corona and superior stalked ovaries. The tendrils are axillary hence are modified branches. Leaves are usually stipulate. Flowers are regular, bisexual but in *Pempe*, they are unisexual and dioecious. Sepals—3 to 5, united. Petals—3 to 5, united below. The ornamental corona of hairy outgrowths in 2 or 3 rows arises from the tube of the corolla. Stamens—3 to 5, free. Carpels—3, united. Ovary—superior, unilocular, seated on a gynophore, with 3 parietal placentas. Fruit—berry with many seeds.

Floral formula—K(5) C(5) A5 G(3)

Sub-class—Gamopetaleae

N.O.—Rubiaceae.

Common plants—(1) *Rangan* (2) *Kadamba* (3) *Gandharaj* (4) *Khetpapra* (5) *Manjista* (6) *Gandhali*. (7) *Moynakanta*.

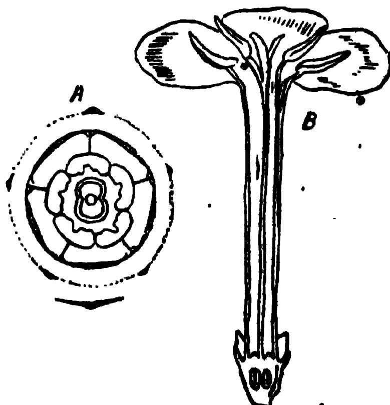


Fig. 261.

A—Floral diagram of Compositae. B—Longitudinal section of *Rangan* flower.

General characters—Plants may be trees, shrubs or herbs ; some are climbers. Leaves are simple, opposite, decussate and stipulate. The stipules are interpetiolar. Flowers are solitary or clustered, bisexual and regular. Sepals—4 or 5, united. Petals 4 or 5, lobed. Stamens epipetalous and equal to the corolla lobes. Carpels—2, syncarpous. Stigma—2, free ; style—one, long. Ovary—inferior, 2—10 celled. Fruit—berry, drupe or capsule.

Uses—Many possess tonic and purgative properties. *Manjista* and other plants yield dye and tannin. Among the important commercial products of the family are coffee and quinine.

Floral formula—K(4 or 5) $\overline{C\ (4\ or\ 5)\ A}$ 4 or 5 $\overline{G(2)}$

N. O.—Compositae.

Common plants—(1) *Surjamukhee* or Sun flower (Helianthus annuus) (2) *Gandha* (3) *Chandra mallika* (Chrysanthemum) (4) *Kukshima* or Kukur shonka (5) *Kusumphul* (6) *Shoregonja* (7) *Keshurta* (8) *Hinche* (9) *Hatichoke* or Artichoke.

Chief characters :—Herbs or shrubs. Leaves—simple and exstipulate. Flowers—many, small, all collected on a head or capitulum. Ovary—inferior. Fruitlets are usually dispersed by wind.

Type—*Surjamukhi* or Sunflower

The plant is an annual herb cultivated in gardens. It flowers in winter. It scarcely attains a height of 3 yards. The stem branches in the upper part. It is nearly tubular with loose pith.

Leaves are simple, exstipulate, alternate, cordate and pinnately reticulate.

Flowers arise at the head of stem or branches. The whole mass is not a single flower but an aggregate of many florets. Hence the order is named Compositae. The flower is called sunflower as it turns its face towards the

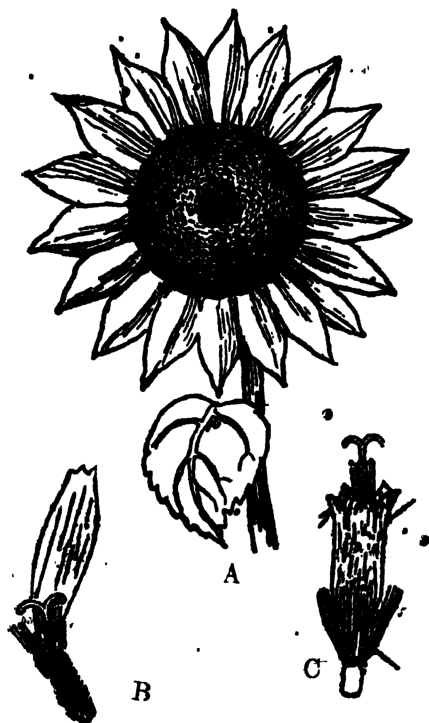


Fig. 262.
Surjamukhi. A—Capitulum. B—Ray floret. C—Disc floret.

sun. All the florets are collected together on the flat surface of a fleshy receptacle (**capitulum**) which is embraced at its bottom by a large number of bracts called involucre. The

florets develop centripetally so the younger ones are in the middle. They are of two kinds. Those towards the periphery are ray-florets and those in the centre are disc-florets. All the florets are usually situated in the axils of small hairy bracts called paleae.

The **ray florets** are mostly sterile. They consist of only sepals and petals. Calyx is pappus consisting of two small hairs at the base of corolla. The petals are united to form a short tube at the base, which is spreading above in the form of a flat strap (**ligulate**).

The **disc-florets** are complete, bisexual, regular and epigynous. As in ray florets the calyx is pappus or hairy. The petals are 5, united to form a tube which is swollen at the base. Stamens are five and epipetalous. The filaments are free but their anthers are united (**syngenesious**). The syncarpous gynecium consists of two carpels. The two stigmas are free and the single style passes through the anthers. The inferior ovary is unilocular containing only one erect ovule. The placentation is basal.

The fruit is simple, dry, indehiscent and a **cypsela**. The persistent calyx appearing in the form of short wings helps the dispersion of fruits by wind. The seeds are exalbuminous which show epigeal germination.

Pollination—The inconspicuous florets forming a crowded mass serve to attract insects. The effect of their forming a clustered body is enhanced by the ligulate florets on the margin. The insects crawl over the mass in search of honey present within the corolla tube and thus all the florets are at the same time pollinated by the same insect. The stamens are protandrous and when ripe, they shed their

pollen inside the tube of the anthers over the head of the immature style. A little later, when the style grows in length through the anther tube it pushes up the pollen out of the tube. It now opens its stigmatic heads in order to receive pollen from another flower. If intercrossing fails, the stigmatic lobes bend down to receive the pollen from the corolla tube thus effecting self-pollination.

N. O.—Apocynaceae.

Common plants—(1) *Karabi* (2) *Nayantara* (3) *Tagar* (4) *Kat-champa* (5) *Kalika phul* (6) *Malati* (7) *Karamcha* (8) *Kurchi* (9) *Chhatim.*

General characters :—Trees, shrubs or climbers always with milky latex. Leaves—simple, exstipulate, opposite or whorled. Flowers—

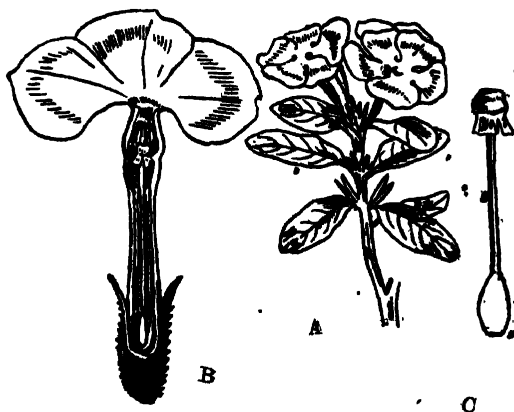


Fig. 263.

Nayantara. A—Floral shoot. B—Flower. C—Carpel.

complete, regular and hypogynous. Sepals—5, united. Petals—5, hypocrateriform with contorted aestivation. Stamens—5, free and

epipetalous. Carpels—2, united by their styles and stigmas but free in the ovaries. Stigma—dumb-bell-shaped. Fruit—a pair of follicles. Seeds bearing a tuft of hairs.

Floral formula—K(5) C(5) A5 G(2).

N. O.—Asclepiadaceae.

Common plants—(1) *Akanda* (2) *Ananta mool.*

This family closely resembles Apocynaceae.

General characters :—Mostly climbing shrubs, sometimes erect ; always with milky latex. Leaves—simple, opposite, decussate, exstipulate. Flowers—regular, hermaphrodite. Sepals—5, united, Petals—5, united, usually twisted in aestivation. Corona—always present outside the staminal column. Stamens—5, gynandrous. Anthers—with pollinia. Carpels—2, united by style and stigma. Fruit—a pair of follicles.

Type—*Akanda.*

The plant is an erect bushy shrub. The stem and leaves abound in milky latex which being distasteful to cattle protects the plant.

Leaves are simple, exstipulate, nearly sessile, opposite, decussate and covered on the under side with a white waxy down. Flowers are in cymose umbels. They are regular, hermaphrodite and hypogynous. Sepals, petals and stamens are all 5. Petals are 5 lobed, campanulate and valvate. There are 5 large, waxy bodies, curiously recurved alternating with the petals and arranged round the central column. These form the corona which is adnate to the

staminal filaments. In the centre of the flower there are two free ovaries headed by the united style supporting a pentangular disc-like stigma. At each angle of the stigma there is a sticky gland to which 2 pollinia are attached, each of which belonging to two anthers.



Fig. 264.

Akanda. a—Floral shoot. b—Flower: c—Flower with tho sepals and petals removed. d—Carpel. e—Fruit. f—Pollinia.

Fruit is a pair of follicles which when ripe bursts to liberate the comose seeds. They are then dispersed by wind.

Pollination is effected by bees which take away the pollinia

Floral formula—K(5) $\overline{C(5)\ A(5)}$ $\underline{G(2)}$.

N. O.—Solanaceae.

Common plants—(1) *Aloo* or Potato (Solanum tuberosum) (2) *Begoon* (3) *Belati begoon* (4) *Lanka* (5) *Dhutra* (6) *Tamak* or Tobacco (7) *Aswagandha* (8) *Kantikari* (9) *Tapari.*

Chief characters :—Herbs or shrubs with alternate, exstipulate leaves. Most of the plants are poisonous. Corolla—rotate or funnel shaped. Ovary—usually 2-celled, slightly displaced from the median plane which makes the flower slightly irregular. Placentation—axile. Fruit—berry or capsule. Seeds—numerous.

Type—*Dhutra.*

This herb is a common weed of Bengal. The stem branches scorpioidly. The leaves are large, unsymmetrical, simple, exstipulate and pinni-veined. The solitary flowers are complete, hypogynous, and slightly irregular. Sepals—5, tubular. Corolla of 5 petals forms a long white funnel. Stamens—5, free and epipetalous. Carpels—two which form at first a 2-celled and then 4-celled ovary due to the outgrowth and displacement of the placentas, which arise on the central axis.

Fruit is a dry capsule which opens in four valves. There are many prickles covering the whole fruit. These protect the numerous seeds which, though poisonous to human beings, are eaten by some birds.

Pollination.—The flowers open at night and exhale a disagreeable, musky smell which along with the white colouration of the petals attract moths to transfer the pollen from one flower to the other. Honey is secreted at the base of the ovary.

Other plants—*Tamak* is a small herb covered with glandular hairs to keep off animals. Flowers arise in cymes. Fruit, when ripe, opens in two valves. *Aloo* stem produces many underground tuberous branches which form the storehouses of reserve starch.. The leaves are large and pinnately lobed. Corolla is rotate, the lobes of which



Fig. 265
Lanka. A—Shoot. B—Flower. C—Fruit. D—Seed.

alternate with the sepals. The anthers united at their ends dehisce by pores. Fruit is a berry. *Begoon* is known for large berry fruits. *Lanka* is cultivated everywhere for its pungent fruits used in curries and pickles. The white flowers are in cymes. There are many varieties producing small, large and swollen fruits.

Uses—*Tamak*, *Datura* etc., produce poisonous alkaloids and they are used medicinally. From *Begoon*, *Aloo*, *Tomato*, etc., articles of food are derived as they produce ebible fruits or tubers. *Aswagandha*, a common weed in N. Bengal, is well-known for its medicinal properties.

Floral formula—K(5) C(5) A5 G(2).

N. O.—Convolvulaceae.

Examples—(1) *Kalmi-shag* (2) *Ranga-aloo* (3) *Tarulata* (4) *Bhumi-kumra* (5) *Alokelata*.

Plants are usually shrubs and twining herbs. Leaves—simple alternate, exstipulate, cordate or hastate, sometimes with hairs below. Inflorescence—dichasial cymose. Flowers—complete, large, coloured, axillary, regular, hypogynous and bracteate. Sepals–5, slightly united at the base, usually persistent, imbricate. Petals—5, united, with plaited aestivation, bell or funnel-like in forms. Stamens–5, free, epipetalous. Carpels—2, united. Ovary—2 to 4-celled, superior, with axile placentas on which 4 ovules develop. Stigma—bilobed. Fruit—berry or capsule with 4 albuminous seeds.



Fig. 266.

Ranga-aloo. a—Shoot. b—Flower. c—Ovary. d—Section of ovary. e—Transverse section of ovary. f—Floral diagram.

Floral formula—

K5 C(5) A5 G(2).

This order is closely allied to Solanaceae from which it is at once distinguished by the number of ovules or seeds.

N. O.—Verbenaceae.

Examples. (1) *Bhant* (2) *Nishinda* (3) *Shagoon* or Teak:

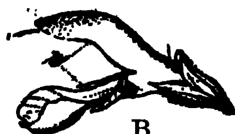
Plants—trees, shrubs or herbs. Leaves—simple, opposite, decussate or whorled. Inflorescence—racemose or cymose. Flowers complete, irregular, zygomorphic, hypogynous and usually bracteate. Sepals—5, united, persistent. Petals—5, united, bilabiate. Stamens—4, free, didynamous, epipetalous. Carpels—2, united. Ovary—superior, 2 to 4-celled, with 1 ovule in each cell. Placentation—axile. Style—terminal. Fruit—berry, drupe or capsule with exalbuminous seeds.

Fioral formula—K(5) C(5) A4 G(2).

This is closely allied to Labiatae from which it differs in having terminal style and the ovary not being deeply 4 lobed. From Acanthaceae it differs in the structure of ovary.

N. O.—Acanthaceae.





B

Fig. 267.
Basak. A—Spike.
B—Flower.

Common plants—(1) *Basak* (Adhatoda vasica) (2) *Kalmegh* (3) *Kulekhara* (4) *Nil-lata.*

Chief characters :—Usually herbs. Stems with swollen nodes. Leaves—simple, opposite and exstipulate. Flowers are with conspicuous bracts. Corolla—bilabiate. Stamens—usually didynamous. Ovary 2-celled, superior.

Type—*Basak.*

This is a bushy under-shrub. The branches are swollen at the nodes. The leaves are simple, lanceolate, entire, exstipulate, opposite and decussate. At the ends of stems or branches flowers arise in clusters on long spikes. They are sessile and placed at the axils of leafy bracts Each

flower has also 2 bracteoles besides a large bract. Flowers—complete and irregular. Sepals—5, united. Petals—5, united, bilabiate, upper lip overhanging over the spreading lower lip. Stamens—2 and epipetalous. Carpels—2 forming a syncarpous, superior, 2-celled ovary with a slender style and two stigmas. Placentation—axile. Fruit—capsule with two seeds.

The presence of retinacula or hook-like structures supporting the ovules is characteristic of many genera of this family. In many genera, cystoliths occur in the leaves.

Use :—*Basak*, *Kulekhara* ,and *Kalmegh* are medicinal plants.

Floral formula—K(5) C(5) A4 G(2).

N. O.—Scrophulariaceae.

Common plants :—(1) *Basanti* (2) *Brahmi shak* (3) *Bhumi nim* (4) *Snapdragon*

Chief characters :—Mostly herbs. Leaves—usually opposite, exstipulate. Flowers—hermaphrodite, irregular. Corolla—usually personate, sometimes bilabiate. Stamens—4, didynamous. Ovary—two-celled, many-ovuled. Fruit—a capsule containing many seeds.

Floral formula—K (5) C (5) A 4 G (2)

This is very closely allied to Solanaceae from which it differs in having (1) opposite leaves, (2) personate or bilabiate corolla, (3) stamens fewer than corolla lobes, and (4) carpels in median plane.

Basanti is a common weed appearing in the rainy season on old walls producing small yellow flowers. *Brahmi shak* grows plentifully near the edge of water and is well-known for its medicinal properties.

N. O.—Boraginaceae.

Hati-shunr is the well-known example.

Plants are usually herbs with succulent stems covered with hairs. Leaves—simple, alternate, often with cystoliths. The flowers are regular, small and on scorpioid cymes; sometimes large and brightly



Fig. 268.

Hatishunr. A—Shoot. B—Flower. C—Corolla. D—Ovary. E—Fruit.

coloured. Sepals—5, united, lobed, inferior. Petals 5, united, lobed, rotate. Stamens—5, free, epipetalous, filaments short. Carpels—2, united into 2 or 4 lobed ovary; style—mostly gynobasic, 2-4 fid or simple. Fruit—schizocarp breaking into 2 or 4 nutlets, or a drupe.

Floral formula :—$K(5)\ \overline{C(5)\ A5}\ G(\underline{2})$

N. O.—Oleaceae.

Examples—(1) *Juin* (2) *Bela* (3) *Mallika* (4) *Kunda*, (5) *Sheuli*.

Plants—usually shrubs, sometimes climbing. Leaves—simple, opposite, decussate. Flowers—solitary or in panicles, regular, complete, sometimes unisexual or polygamous. Sepals—4 lobed, inferior. Petals—4 to many, united. Stamens 2, free, epipetalous. Carpels—2, united. Ovary—superior, 2-celled. Ovules—1 or 2 in each cell. Fruit—dry capsule or berry with albuminous seeds.

Floral formula :—K(4) $\overline{C(4)\ A2}$ $G\underline{(2)}$

N. O.—Labiatae.

Common plants—(1) *Tulsi* (Ocimum sanctum) (2) *Shwet drone* (3) *Rakta drone* (4) *Pudina.* (5) *Ghalghasi* (6) *Topemari.*

Chief characters :—Mostly herbs. Stem square. Leaves opposite. Aromatic smell. Inflorescence verticillaster. Corolla bilabiate. Stamens didynamous. Ovary 4-lobed with gynobasic style.

Type—*Tulsi.*

This is a woody little plant having many glandular hairs scattered over the surface of stems and leaves. The hairs secrete an ethereal oil for which the plant emits a smell. The stem is square in shape. The branches arise from the axils of opposite leaves. Branching dichasium. Leaves simple, decussate and exstipulate. Flowers arise on stalks which also develop cymosely.

Flowers are complete, zygomorphic, hypogynous and sessile. The irregular bell-shaped calyx of 5 sepals has two lower lobes longer than the upper lobe. Corolla of 5 petals is bilabiate. The upper lip is 4-cleft and the lower one is entire and boat shaped. Stamens are epipetalous and 4, of which 2 are longer than the other two. Carpels

are 2, fused to form a superior syncarpous ovary, a single style and two free stigmas. The ovary is deeply four-lobed. The style is gynobasic, i. e., it springs from the middle of the ovary at the base of the lobes. Fruit consists of four dry nutlets, each containing a small seed.



Fig. 269.
Tulsi, a—Floral shoot. b—Flower. c—Carpel. d—Fruit. e—Floral diagram.

Other plants—*Drone*, *Ghalghasi* have flowers in dense verticillaster inflorescence at the axils of opposite simple leaves.

Floral formula—K(5) C(5) A4 G(2).

Sub-class—Incompleteae

N. O.—Nyctaginaceae.

Examples—(1) *Krishnakali* (Mirabilis jalapa) (2) *Punarnaba* (3) *Bagan bilas.*

Plants—usually herbs or shrubs. Stem—swollen at the nodes. Leaves—simple, usually opposite. Inflorescence—cyme or sometimes umbel. Flowers—regular, bisexual, hypogynous. Several coloured bracts form an involucre. Perianth—5, petaloid, united, inferior,

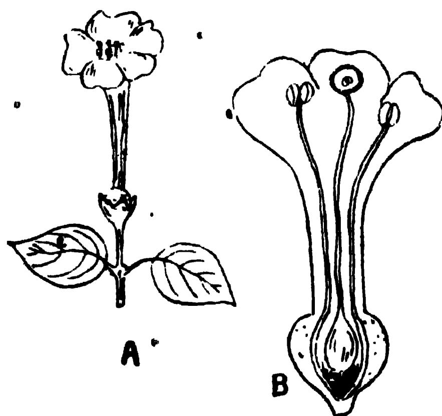


Fig. 270.

Krishnakali. A—Flower. B—Longitudinal section of the flower.

persistent, swollen at the base where lies the ovary. Stamens 5 or more, free, unequal in length. Carpel - 1. Ovary—superior, unilocular with one ovule. Fruit—achene. Seed—albuminous.

Floral formula—P(5) A∞ G1

Other plants—*Punarnaba* is a medicinal herb used for dropsy. In *Bagan bilas*, the three rose-coloured bracts in a cluster render the plants ornamental. In *krishnakali*, the five green bracts must not be mistaken for a calyx.

N. O.—Amarantaceae.

Examples—(1) *Morog phul* (2) *Gul makmal* (3) *Apang* (4) *Kanta-natia* (5) *Data-shag* (6) *Champa-natia.*

Plants—usually herbs. Stem—soft, erect. Leaves—simple, alternate or opposite. Flowers are very minute, usually in spikes or in cymes, hermaphrodite or unisexual, regular, with bracts and bracteoles.



Fig. 271.

Kantanatia. A—Shoot. B, C—Flowers (male and female). D—Ovary.

Perianth—dry, membranous, persistent, of 5 leaves. Stamens—1 to 5, free, inferior. Carpel—1 with unilocular and one-ovuled ovary. Fruit—utricle with albuminous seed.

Floral formula—P(5) A5 G1

Moragphul and *Gul makmal* are garden plants noted for their ornamental inflorescences. The stems of *Data-shag*, *Champanate* etc., are used in Indian curries.

N. O.—Polygonaceae.

Examples – (1) *Ban-palang* (2) *Chuka-palang* (3) *Panmarich.*

This order is very closely related to Amarantaceae, from which it differs mainly in having ochreate stipules and triangular ovary of 3 carpels.

Floral formula :—P(5) A5 G(2)

N. O.—Urticaceae.

Examples—(1) *Kantal* (Artocarpus integrifolia) (2) *Bot* (Ficus benghalensis) (3) *Aswatha* (Ficus religiosa) (4) *Dumur* (Ficus hispida) (5) *Bichuti* (6) *Tunt* or Mulberry (7) *Bhang.*

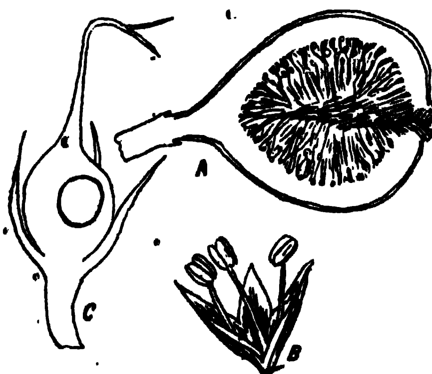


Fig. 272.

Bot. A—Inflorescence. B – Male flower. C—Female flower.

Plants—trees, shrubs or herbs. Leaves—simple, alternate, rarely opposite, stipulate, stipules usually convolute. Stems—usually with a milky juice. Flowers are small, densely arranged on raceme, spike, hypanthodium or cymose inflorescences ; they are regular, unisexual, monoecious or

dioecious or polygamous. Perianth—4, in one or two whorls, polyphyllous or gamophyllous. Stamens—equal in number and opposite to perianth lobes. Ovary—superior, unilocular with one ovule. Fruit—simple (achene) or multiple (syconus or sorosis) Seeds—usually exalbuminous.

This order is usually divided into several tribes which are diverse specially in the forms of their inflorescences. *Bot, Aswastha* have sycoñus fruits. *Kantal* has sorosis fruits. All of them have milky juice in their stems. *Bhang*, cultivated for its narcotic leaves used as *siddhi*, has its young inflorescences resinous which are smoked as *charas*. The leaves of *Tunt* are used for feeding silkworms.

N. O.—Euphorbiaceae.

Common plants—(1) *Rerhi* or Castor plant (Ricinus communis) (2) *Sij* (3) *Monsa sij*. (4) *Lalpata* (5). *Bagh-bharenda* (6) *Lal-bharenda* (7) *Bajbaran* (8) *Joypal*. (9) *Muktajhuri* (10) *Amloki* (11) *Nole* (12) *Pituli*.

Chief characters—trees, shrubs or herbs with watery or milky latex. Leaves—simple, alternate mostly with free stipules. Inflorescence—various, sometimes cyme, sometimes cyathium. Flowers—calyx and corolla both present or absent, in some only calyx present. Flowers—unisexual, monoecious or dioecious. Stamens—1 to many. Carpels—1 to many but usually three ; when more than one, always syncarpous and chambers according to the number of carpels. Fruit—schizocarp, capsule or drupe.

Type—*Rerhi* or **castor plant.**

This is an annual herb or a shrub producing large,

peltate, palmati-partite, alternate leaves with serrate margin. Petioles are long and hollow.



Fig. 273.

Rerhi. A—Leafy shoot. B—Inflorescence. C—Stamens. D—Carpels. E—Section of ovary.

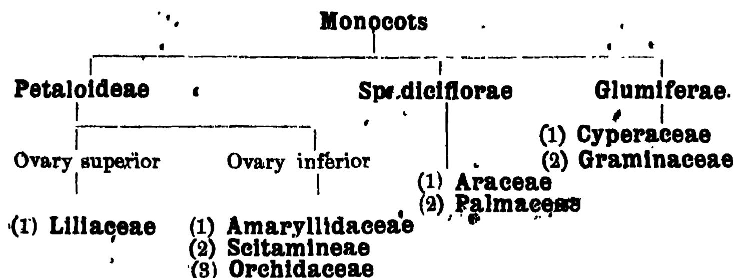
Flowers arise at the ends of stems or branches in panicles. They are all unisexual and monoecious. On the same rachis arise flowers of which the males are crowded at the base and the females at the top. Both the flowers have only 3 to 5 sepals to protect the essential organs when in bud. The corolla is entirely absent. In male flowers the stamens are numerous and so branched that they look like bunches. In female flowers the 3 carpels are fused into a 3-celled superior ovary with 3 bifid styles.

Fruit is a spinous capsule which divides into 3 parts each contaning one oily seed. The oil is stored as food for the young plants.

Other plants :—*Lalpata* and all Euphorbias have a peculiar cyathium inflorescence. This consists of a cup, formed of a number of bracts united together, in the interior of which are many male flowers surrounding a central female flower. Each male flower consists of a single stamen at the axil of a bract. The female flower has three carpels fused and seated on a short gynophore. The fruit is a schizocarp consisting of three cocci. In *Mansha-sij*, the stipules are thorny. In *Sij*, the leaves are transformed into spines. The latex in them is poisonous. In *Amloki*, *Nole* and *Bhuni-amla*, the small branches bearing distichous leaves and fruits on the lower side look like compound leaves.

Uses :—The castor oil is valued for lubricating machinery, for tanning hides, for lighting, for soaps, candles, etc. *Muktajhuri*, *Castor*, *Joypal* etc. are used as purgatives. *Sij*, *Mansha-sij* and other plants are poisonous. Some yield dyes. The *Latka* of E. Bengal and *Akrote* are edible fruits.

MONOCOTYLEDONS



CLASS—MONOCOTYLEDON

Sub-class—Petaloideae

N.O.—Liliaceae.

Common plants (1) *Pianj* (Allium cepa) (2) *Sata-muli* (3) *Ghrita kumari* (4) *Ulat chandal* (5) *Kumarika.*

Chief characters :—Usually herbs with underground stems in the forms of rhizomes, tubers or bulbs producing fibrous roots ; sometimes aerial. Leaves—large, sheathing at their bases, parallel-veined, in some cases succulent. Inflorescence usually racemose. Flower—regular, trimerous. Perianth petaloid. Stamens—usually six. Ovary—superior, 3-celled. Fruit—berry or capsule.

Type—*Pianj* or **onion.**

The plant is a herb with a peculiar smell. The stem is a tunicated bulb from the base of which fibrous roots arise in a cluster. The inner scaly leaves protected by their outer ones store food and become fleshy. The aerial leaves are radical, simple, hollow, parallel-veined with sheathing base from the axils of which hollow scapes arise annually

in winter. Flowers appear in a simple umbel enclosed in an involucre of scaly bracts. Flowers are complete, regular, trimerous, having perianth of 6 segments in 2 whorls. Just inserted on them are 6 stamens. Carpels are 3 fused to form a superior 3-celled ovary with axile placentation. Ovules are two in each cell. Fruit is a capsule dehiscing loculicidally.

Other plants—*Ulatchandal* has the leaf-tips tendrillar by which the plant climbs. Flowers are in racemes. The

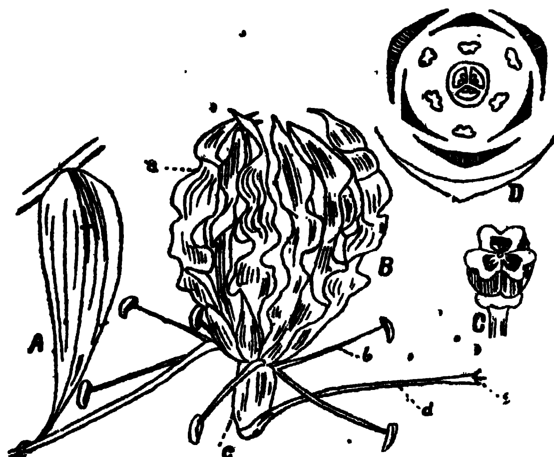


Fig. 274.

Ulat chandal. A—Leaf with the coiling tip. B—Flower. a—Petal. b—Stamen. c—Ovary. d—Style. s—Stigma. C—Section of ovary. D—Floral diagram.

wavy petals are showy and curl back when they blossom. The long style bends away. *Kumarika* is also a climber climbing by tendrillar stipules. It differs from other plants of the family in having net-veined leaves and small dioecious

flowers. The flowers are all unisexual. *Ghrita kumari* has the leaves very fleshy. They contain mucilage in which water is stored. *Shatamooli* is a straggler with a creeping rhizome. The branches are cladodes.

N. O.—Amaryllidaceae.

Common plants (1) *Rajenigandha* (2) *Sukhadarsan.*

Chief characters—The plants differ from those of

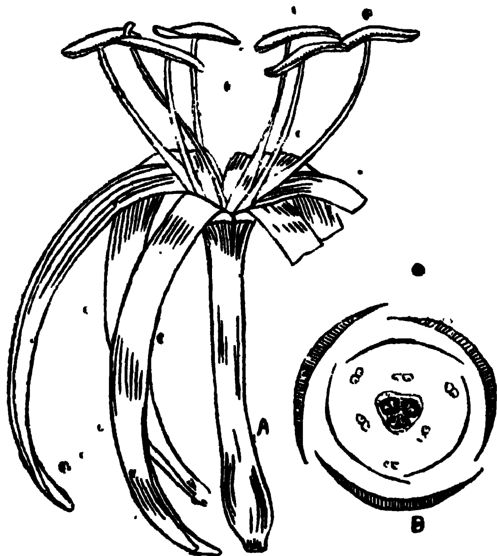


Fig. 275

Shukhadarsan. A—Flower. B—Floral diagram.

Liliaceae in having inferior ovary. Plants are herbs always with underground bulbs. Leaves are radical. The scape bears a number of regular, complete flowers with petaloid perianth in two whorls. Corona sometimes is present. Stamens—6 and epiphyllous. Carpels—2, fused to form a 3-celled inferior ovary with many albuminous seeds.

N. O.—Scitamineae.

This large order is divided into three sub-orders.

(a) **Musaceae** (b) **Zingiberaceae** (c) **Cannaceae.**

They agree closely in their vegetative characters as well as in carpels differing mainly in respect of stamens.

Chief characters of the order :—Herbs with underground rhizomes. Leaves—radical, large, pinnately veined and with sheathing petioles. Flowers—bisexual, zygomorphic or asymmetrical. Stamens—6, of which some may be perfect and others modified. Ovary—inferior, three-celled with axile placentation. Ovules—many. Fruit—capsule or berry.

(a) Sub-order—Musaceae.

Type—*Kola* or banana.

The tall, aerial, soft stem covered by the overlapping leaf-sheaths is not really the stem. The real stem is a fleshy rhizome from which fibrous roots grow downwards and leaves upwards. At the time of flowering a white long solid cylinder grows up with many large leaves to produce at its end many flowers and fruits. The cylinder looks like the trunk of the plant but it is really a scape which growing from the rhizome pushes its way through the leaves. Each leaf has a strong mid-rib from which many secondary veins grow towards the margin. The ptyxis of the leaf is convolute. The leaf-sheaths are large, boat-like containing air cavities and raphides.

The scape continues to grow beyond the stem and forms the rachis of the well-known conical spadix on which the flowers arise in different clusters. Each cluster is protected by a concave leathery spathe which is dark red on the

inside. Towards the base of the drooping spike each spathe encloses at its axil two rows of several fertile flowers. The flowers are female at the base, perfect in the middle and male at the top. The spathes open in succession from the

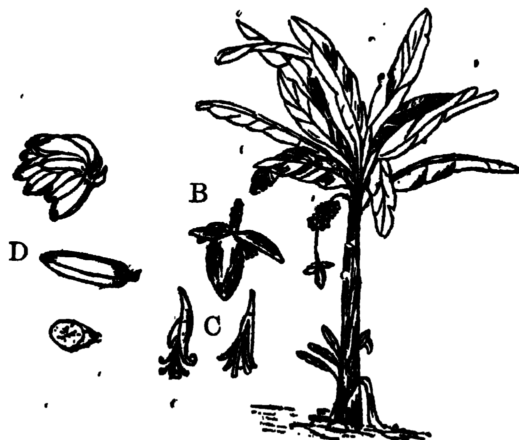


Fig. 276.

Kola. A—Plant. B -Spadix. C—Flowers. D—Fruits.

base to the apex along with the maturity of each successive row of flowers. The main spike opens racemosely but the flowers of each cluster open cymosely. The petaloid perianth consists of 6 segments in two whorls ; 3 of the outer and 2 of the inner segments are united to form a 5-toothed tube with a slit throughout the length, in which the sixth inner segment is placed. The 5 stamens are perfect and the sixth is abortive. Carpels are three fused to form an inferior 3-celled ovary with axile placentation. Fruit is a berry. Seeds are usually absent.

Other plant of the sub-order—*Pantha padap* or traveller's tree bears two rows of large plantain-like leaves on a tall aerial stem and is often planted in our gardens.

(b) Sub-order—Zingiberaceae.

Common plants (1) *Ada* (2) *Halood* (3) *Ban-ada* (4) *Am-ada* (5) *Dulal-champa* (6) *Bhui-champa* (7) *Alachi* (8) *Santi.*

Type—*Dulal-champa.*

This herb has a fibrous rhizome from which radical leaves arise. The leaves are lanceolate, sessile, distichous and with sheathing petioles. The fragrant, white bracteate flowers are in spikes. Sepals are 3 forming a tube within which there is a long tube of 3 petals. One of the petals called labellum is spreading and forms the seat of insects. Stamens 6 in 2 whorls only one of which has a perfect anther. The outer three are petaloid staminodes. The inner two are glandular. Carpels same as in banana. Fruit is a capsule.

(c) Sub-order—Cannaceae.

Common plants (1) *Sarbajaya* (Canna indica) (2) *Pati.*

Type—*Sarbajaya.*

Roots, stems and leaves are as in other Sub-orders. The flowers are asymmetrical. They arise in racemes. Bracts embrace flowers. Sepals—3, free. Petals—3, united into a tube. Stamens—6 of which 5 are petaloid staminodes. The sixth stamen has half anther lobe fertile and the other half with the filament forms a petaloid body. Carpels same as in other Sub-orders. Fruit—capsule.

Uses of the plants of the family—*Arrowroot* is the starch obtained from the fleshy rhizome of the plant. Similarly



Fig. 277.
Swarbajaya. A—Flower. B—Floral diagram.

ginger, turmeric of market are the rhizomes of those plants. The aromatic and pungent seeds of *Alachi* which grows in the hills are used as spices. *Pati* grows in Assam and East Bengal. The split stems are used for making mat or *sital-pati.*

N. O.—Orchidaceae.

Examples—*Rasna* (Vanda Roxburghii), commonly seen on the branches of mango and other trees as an epiphyte, and other Orchids growing abundantly in the hilly forests of the Himalayas.

Plants are all epiphytic herbs with branched aerial roots and green leaves; some are terrestrial. Flowers—comple te, irregular, epigynous.

Perianth—6 of which 3 outer leaves are nearly equal and of the 3 inner leaves, two lateral are equal while the middle one called **labellum** is the largest, different in form and sometimes with a spur

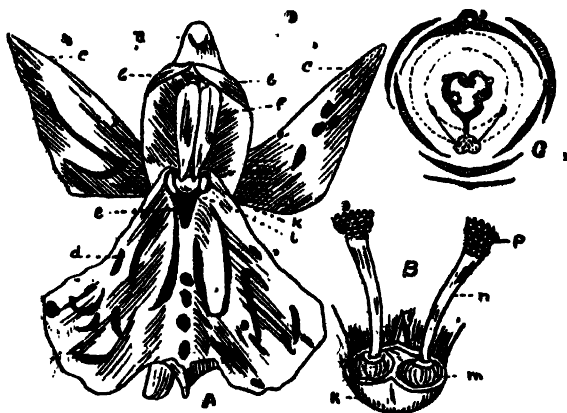


Fig. 273.

Orchid. A—Flower. a,c—Outer perianth leaves. b—The two inner perianth leaves. d—Labellum. e—Entrance to the spur. f—Stamen. k—Staminode. l—Cup. B—Caudicle. k—Cup. m—Disk. n—Caudicle. p—Pollinium. C—Floral diagram.

containing honey sought after by insects. Stamen is solitary, rarely two, **gynandrous** i. e., adherent to the stigma forming a column called **gymnostemium** at the base of which there is a small round, knob-like projection called **rostellum**. The two pollen-sacs of the anther are nearly parallel and each contains a club-shaped **pollinium** or pollen mass which is connected with the rostellum by a slender stalk called **caudicle** and a **disk** at the base. On the two sides of the stamen at the base there are two staminodes. Situated slightly below the rostellum and on the two sides of it are two sticky stigmas while the rostellum itself represents the abortive stigma. Carpels—3, united into an inferior, much twisted, unilocular ovary with 3 parietal placentas on which many ovules appear. Fruit—

capsule dehiscing loculicidally into 3 valves. Seeds—very minute so they are easily dispersed by wind.

Pollination :—When an insect sits on the labellum, the landing place, and seeks for the honey concealed in the spur, it touches in its forehead the fragile rostellum which breaks and consequently the pollinia with their caudicles and disks stick to its head. When the insect visits the next flower with the whole pollinia of the first flower removed and tries to get the honey, the pollinia by means of the bending of their caudicles meet the stigma and pollinate it. The stigma, being sticky, can capture at least some of the grains if not the whole pollininm.

Sub-class—Spadicifloreae.

N. O.—Aroideae or Araceae.

Examples—(1) *Kochoo* (Colocasia antiquorum) (2) *Man-kàchoo* (3) *Ghet-kochoo* (4) *Goja-pipul* (5) *Bara-pana* (6) *ol*.

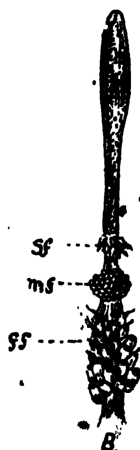


Fig. 279.
Kachoo Spadix.
ff—Female flowers,
mf—Male flowers.
Sf—Neuter flowers.

Plants—herbs with rhizomes, tubers or corms as stems which may also be climbing by means of aerial roots. Leaves—simple or compound, alternate, usally radical. Ventation is usually palmately reticulate. Flowers are usually unisexual and arise on spadix enclosed by a large fleshy spathe. The head of spadix is occupied by closely arranged male flowers below which are some abortive flowers while the female flowers are at the base of the spadix; sometimes the neuters are above the males. The flowers are achlamydeous. Each male flower has a single 2-celled anther. Each female flower consisting of a single pistil has unilocular ovary with ovules on 2 or 3 placentas. Fruits—usually berries with many albuminous seede.

In *Gajapipul* the stem is climbing and the flowers are hermaphrodite. *Pana* which is common in tanks has obcordate leaves and fibrous roots.

N. O.—Palmaceae.

Examples—(1) *Narikel* (Cocos nucifera) (2) *Tal* (3) *Khejur* (4) *Supari* (5) *Golepata* (6) *Beth.*

Plants are usually trees with tall, unbranched, or rarely branched, woody stems (caudex). Leaves—pinnately or pal-



Fig. 280.

A—Spadix. B, C—Flowers. D, E—Floral diagram.

mately divided, with sheathing base, large and form a crown at the head of the plant. Flowers arise on much-branched spadix enclosed in a woody spathe. They may be unisexual or bisexual. Perianth consists of 6 sepaloid leaves in two

series, 3 in each, inferior. Stamens—usually 6, free. Carpels—3, united into 1 or 3 celled superior ovary. Fruit—1 to 3 seeded drupaceous nut.

Floral formula—P3 + 3 A3 + 3 G(3)

Uses—*Tal, Narikel, Supari* stems are used in building and other constructions. The leaves of *Golpata* are used in the construction of thatched houses. The fibres of *Narikel* fruits are the materials for cordage. The flexible stems of *Bet* are used for walking sticks, chairs and umbrellas for which they are largely exported to foreign countries. The sugary juice of *Khejur, Tal* collected from the incised stems is boiled down for making sugar or *gur*. It is also fermented for making wine. The albumen of *Narikel* not only serves as a delicious food but furnishes excellent cocoanut oil. The ruminated albumen of *Supari* is universally chewed in India. The oil obtained from *Tal* fruits is largely utilised in the manufacture of candles, soap, etc.

Sub-class—Glumiferae.

N. O.—Cyperaceae.

Common plants—(1) *Mootha* (2) *Kasur* (3) *Madur kati*.

This Order is very closely allied to the following important Natural Order Graminaceae.

Chief characters—Annual or perennial herbs with rhizomes or tubers. Aerial stems—solid and triangular, sometimes round. The nodes are not swollen. Leaves are with sheathing petioles and **tristichous** i. e., arranged in 3 ranks. Sheaths are closed in front of leaves. Ligules are

absent. Flowers are in spikes and each is borne in the axil of a single bract. Perianth is absent or there are 6 bristles in its place. Stamens 3 in one whorl. Carpels—

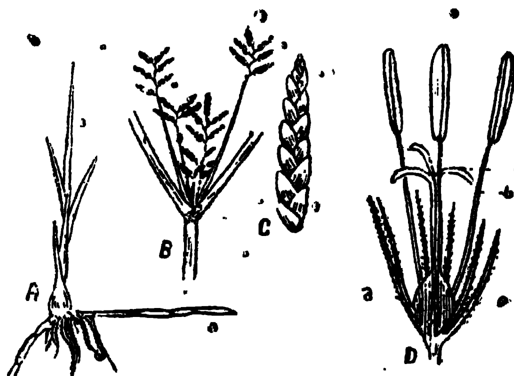


Fig. 281.

Mootha. A—Plant. B—Spikes. C—Spikelet. D—Flower. a—Perianth. b—Stamen. c—Stigma.

2, fused to form one-celled ovary and a single style which is branched at the head bearing 2 or 3 stigmas. Fruit—a nut with an albuminous seed. Pollination take place by the help of wind.

N. O.—Graminaceae,

Common plants—(1) *Dhan* (Oryza sativa) (2) *Gaum* (Triticum vulgare) (3) *Bhutta* or *Maize* (Zea mays) (4) *uk* or Sugarcane (5) *Durba* (6) *Ulooghas* (7) *Chorekanta* (8) *Naul* (9) *Bans* (10) *Kush* (11) *Jab* or Barley (12) *Jai* or Oat (13) *Dedhan* (14) *Nebu ghas* or Lemon grass.

Chief characters :—Plants—annual or perennial herbs. Stems—hollow in the internodes but knotted at the nodes (except *Bhutta, Uk*). Roots—fibrous. Leaves—simple, alternate, parallel-veined, linear with sheathing petioles. The sheath is split down in front. The phyllotaxis is **distichous** i. e., leaves are arranged in two ranks. **Ligules** are at the junction of blade and leaf-base. Flowers are in spikelets. Each spikelet has **two glumes** at the base, one above the other. Flowers may be one or several. The upper flowers are degenerated. The lower flowers are perfect. Above the inner glume there is the first flower having 2 scales—the lower is called **flowering glume** and the upper **palea.** Above these there are 2, or rarely 3, **lodicules** representing perianth. Stamens—3 to 9, all free. Anthers—versatile and deeply notched at the ends. Carpel—only one. Ovary—superior, one-celled with a single ovule. Styles—two or three. Stigmas—feathery. Fruit—a dry caryopsis of which the pericarp is adherent to the testa.. There is a large endosperm. Germination is hypogeal.



Fig. 282.
Dhan plant with leaves and fruits.

Type—*Dhan* or Paddy.

The stem is an erect hollow culm. Flowers are in panicles. Each spikelet consists of one flower. The palea is provided with a bristle-like body called **awn**. Lodicules are only two. Stamens—6. Styles—two, branched into feathery stigmas.



Fig. 283.

Flower of *Dhan*. a—Empty glume. b—Flowering glume. c—Palea. d—Lodicules. e—Stamens. f—Ovary. g—Stigma.

Other plants—*Gaum* has its spikelets consisting of 3 or 4 flowers. The stamens are 3. In *Bans*, the stamens are 6; the lodicules are 3 in number. In *Bhutta*, the flowers are monoecious.

Pollination—Flowers are all anemophilous.

Uses—The nutritious endosperm of *Dhan*, *Gaum*, *Bhutta* forms our staple food. *Bans* stems are extensively used as supports or pillars for thatched houses and for making sticks, umbrellas, etc. *Bans* is also extensively used for the manufacture of paper. The sugar of commerce is prepared from *Uk* stems which abound in sugary juice. *Khuskhus*, and *Nebu ghas* or Lemon grass furnish fragrant essential oils. Other grasses are used in matting and for the food of cattle.

Exercise

1. What do you understand by the classification of plants? On what characters does such a classification depend? Briefly describe any system of classification known to you. Illustrate your answer with indigenous examples.—C. U. 1925, 1920.

2. State the general principles of classification of plants.—C. U. 1931, 1928, 1917.

3. Give an outline of any system of classification.—C. U. 1926, 1924, 1913.

4. By referring to plants known to you illustrate what is meant by the terms—Natural Order, Genus, Species and Variety.

5. How do Monocotyledons differ from Dicotyledons? Are these differences absolute?—C. U. 1919.

Hints—Absolute differences are (1) Monocot stem has many scattered and closed bundles but Dicot bundles are in one ring, open and limited in number. (2) Monocot seed has a single cotyledon but in Dicot the cotyledons are two in number (3) Monocot flowers are trimerous but Dicot flowers are other than trimerous.

6. What are Cryptogams and what are Phanerogams? Point out the main differences between the two.

7. Give the characters of the Natural Order Anonaceae with an example and sketches.—C. U. 1933, 1925.

8. Describe the Natural Order Cruciferae with special reference to the leaves, inflorescence and androecium.—C. U. 1927, 1919, 1912.

9. How would you recognise plants belonging to the Natural Order Malvaceae. Mention plants of economic importance of this Order.—C. U. 1931, 1929, 1923, 1922, 1917.

10. Give the characteristic features of the Natural Order Leguminosae indicating particularly how pollination is brought about.—C. U. 1932, 1930, 1919, 1916, 1913, 1910.

11. Describe in detail the characteristics of the N.O. Cucurbitaceae.—C. U. 1920, 1912.

12. Describe a member of the Compositae with sketches.—C. U. 1932, 1930, 1927, 1926, 1924, 1921, 1918, 1916, 1909

13. Describe the N. O. Solanaceae in detail with sketches.—1929, 1926, 1923, 1921, 1920.

14. Give the general characters of the N. O. Apocynaceae mentioning plants of economical and medicinal importance.—C. U. 1928, 1922 1919, 1918, 1917.

15. Describe the morphological characters of the N. O. Asclepiadaceae.—C. U. 1929, 1926, 1922.

16. Describe the characters by which you would identify plants belonging to the Natural Order Acanthaceae—C. U. 1926, 1923, 1918.

17. Define the Order Labiatae.—C.U. 1923, 1921, 1912, 1914, 1910.

18. Write a short essay on Rubiaceae. How would you distinguish the Order from Compositae—C. U. 1915, 1911.

19. Mention the Natural Orders in which an example can be found—(1) Tetradynamous (2) Didynamous (3) Epicalyx (4) Vexillum (5) Corona (6) Gynobasic.—C. U. 1933, 1928.

20. Describe the inflorescence and androecium in the N.O. Euphorbiaceae. Draw sketches.—C. U. 1927.

21. Describe the inflorescence in the Natural Order Amarantaceae.—C. U, 1919,

22. Give an account of the characteristics of N.O. Scitaminaceae.—C. U. 1929, 1925, 1924,

23. In what respects do Liliaceae, Amaryllidaceae and Zingiberaceae agree and in what respects do they differ from each other,—C. U. 1928, 1926.

24. Describe a member of the Graminaceae.—C. U. 1932, 1920, 1918, 1917, 1915, 1914, 1913, 1919.

APPENDIX

Scientific and vernacular names

E = English names.	H = Hindi names.
Ablus, Ebony (E), Abnus, (H),	Diospyros Ebenum
Ada, Ginger (E), Adrak (H),	Zingiber officinale
Akanda, Gig. swallow wort, Ak,	Calotropis gigantea
Akashbael, Dodder, Akasbael,	Cassytha filimormis
Akashmoni,	Acacia moniliformis
Akrote, Walnut (E), Akhrot (H),	Juglans regia
Alachi, Cardamon (E),	Amomum aromaticum
Aloo, Potato (E), Alu (H),	Solanum tuberosum
Alubokra, Alubukhara (H),	Prunus bokharensis
Alokelata, Kasus (H),	Cuscuta reflexa
Am, Mango (E), Am (H),	Mangifera indica
Amada, Amki-adrak (H),	Curcuma amada
Amloki, Amla (H),	Phyllanthus Emblica
Amrah, Hog-plum,(E) Amarat(H),	Spondias mangifera
Amrool, Wood sorrel, Hatti buti,	Oxalis corniculata
Anantamul, I. sarsaparilla, Salsa,	Hemidesmus indicus
Anaras, Pine apple, Ananasa (H),	Ananasa sativa
Angur, Grape (E), Angur (H),	Vitis vinifera
Ankarkanta, Akola (H),	Alangium Lamarckii
Ansphal, Longan(E), Ansphal (H),	Nephelium Longana
Apang, Chichira latjira (H),	Achyranthes aspera
Aparajita, Amaranth Visnukranti,	Clitoria Ternatea
Apel, Apple (E), Seb (H),	Pyrus malus
Arahar, Pigeon pea, Arhar (H),	Cajanus indicus
Asoke, Ashok (H),	Saraca indica
Aswaganda, Asgand (H),	Withania somnifera
Aswatha, Pipal (H),	Ficus religiosa
Ata, Custard apple, Sharifa (H),	Anona squamosa
Atushi,	Crotalaria retusa

Babla, Acacia (E), Babul (H),	Acacia arabica
Badam, Almond (E), Badam (H),	Prunus amygdalus
Bael, Wood apple (E), Bel (H),	Aegle marmelos
Baganbilas,	Bougainvillea spectabilis
Bagnakha, Tiger-claw, Sher-nui,	Martynia diandra
Bagbarenda, Physic nut, Safedind,	Jatropha curcas
Bajbaran, Tidhara-sehund (H),	Euphorbia antiquorum
Bakul, Malsari (H),	Mimusops Elengi
Bana, Khas-khas (H),	Andropogon squarrosus
Ban ada, Tangli-adrak (H)	Zingiber Casumunan
Bandakopi, Cabbage (E),Gobi (H),	Brassica oleracea, capitata
Ban-narenga, Lak-chana (H),	Biophytum sensitivum
Ban-palang, Spinach, Jal-palam,	Rumex maritimus
Bans, Bamboo (E), Bans (H),	Bambusa talda
Barbati, Cow-pea (E), Lobia (H),	Phaseolus adenanthus
Baramanda, Banda (H),	Loranthus longiflonus
B. pana, Water lettuce, Jalkumbi,	Fistia Stratiotes
Barun, Garlic-pear, Biliana (H)	Crativae religiosa
Basak, Malabur nut, Arusha (H),	Adhatoda vasica
Basanti,	Lindenbergia urticifolia
Batapinebu, Shaddak, Chakotra,	Citrus decumana
Beet, Beet (E), Beet Palak (H),	Beta vulgaris
Begoon, Brinjal (E), Baigoon (H),	Solanum melongena
Bela, Ban-mullika (H),	Jasminum Sambac
Belati-begun, Tomato, B. Baigan	Lycopersicum esculentum
Benebau,	Orabanche indica
Berela, Bariar (H),	Sida cordifolia
Beth, Cane (E), Bet (H),	Calamus tenuis
Bhang, Hemp (E), Charas (H),	Cannabis sativa
Bhant or Ghentu, Bhant (H),	Clerodendron infortunatum
Bharenda, Lal-bharenda (H),	Jatropha gossypifolia
Bhumiamla, Jar-amla (H),	Phyllanthus niruri
Bhumichampa, Bhuichampo (H),	Kaempferia rotunda
Bhumikumro, Bilai-kand (H),	Ipomoea paniculata
Bhuminim, Bhui-nim (H),	Bonnaya brachiata
Bhutta, Maize, Makai (H)	Zea Mays
Bichuti, Nettle (E), Barhanta(H),	Tragia involucrata
Bok, Basna (H),	Sesbania grandiflora
Bot, Banyan (E), Bar (H),	Ficus benghalensis
Brahmishak, Safed chamni (H)	Herpestis monnieria

Chal kumra, Veg. marrow, Kaddu,	Benincasa cerifera
Chalta, Chilta, Chalta (H),	Dillenia indica
Champa, Champak (H),	Michelia champaka
Champa natia, Lal-sag (H) & (E),	Amarantus gangeticus
Chandramallika, Crysanthemum,	Chrysanthemum coronaria
Chhagalbati, Chagool-batee (H),	Naravelia zeylanica
Chhatim, Satiun (H),	Alstonia scholaris
Chhola, Gram (E), Chana (H),	Cicer arientinum
Chhotamanda, Banda (H),	Loranthus globosus
Chichinga, Sn. Gourd, Chachinda	Trichosanthes anguina
Chinerbadam, Ground nut (E),	Arachis hypogaea
Chita (Rang), Bilati-sij (H),	Pedilanthus tithymaloides
Choi, Chava, chab (H),	Piper chaba
Chorekanta, Love thorn (E),	Andropogon aciculatus
Chukapalang, Ambut chukka (H),	Rumex vesicarius
Chupri alu, Choopri-aloo (H),	Dioscorea globosa
Dalim, Pomegranate, Anar (H),	Punica granatum
Dashbai chandi,	Belamcanda chinensis
Datashak, Lal-sag (H),	Amarantus gangeticus
Debdaru, Cedar (E), Dodar (H),	Cedrus deodaar
Dhan, Rice (E), Chaul (H),	Oryza sativa
Dhania, Coriander(E),Dhania (H),	Coriandrum sativum
Dhanras, Lady's Finger, Bhindi	Hibiscus esculentus
Dhedhan, Jugar (H),	Andropogon sorghum
Dhopati, Balsam, Gool Mehandee,	Impatiens balsamina
Dhrone (Rakta), Guma (H),	Leonurus sibicus
Dhundhul, Soapbrush, Ghiaturai,	Luffa aegyptiaca
Dhurba, Dhurb-grass, Doorb,	Cynodon dactylon
Dhutra, Thorn-apple, Dhatura,	Datura fastuosa
Dulal-champa, Butterfly lily (E),	Hedychium Coronarium
Dumur, Fig (E), Gular (H),	Ficus hispida
Esabgul, Ispagul (H),	Plantago ispaghula
Eshermul, Eshermul (H),	Aristolochia indica
Gab, Mangostene, Makur-kendi,	Diospyros embryopteris
Gajar, Horse-radish, Gajar (H),	Daucus carota
Gajpipul, Pathos, Hati-pipli (H),	Scindapsus officinalis
Ganda, Marigold (E), Genda (H),	Tegetes patula
Gandhali, Gundali-khip (E),	Paederia foetida
Gandharaj,Gardenia, Dikmali (H),	Gardenia florida
Gaum, Gam (H), Wheat (E),	Triticum vulgare

Ghalghasi, Chota-pal-kusa (H),	Leucas aspera
Ghentu, Bhant (H),	Clerodendron infortunatum
Ghetkachu, Khain (H),	Typhonium trilobatum
Gila, Garbi (H),	Entada scandens
Gima, Sureta (H),	Polycarpon loeflingiae
Goalelata, Godhapadi (H),	Vitis Pedata
Golap, Rose (E), Gulap (H),	Rosa scentifolia
Golapjam, Rose-apple, Golap-jam	Eugenia Jambos
Golepata, Thatch palm (E)	Nipa fruticans
Goranebu, Bijaura (H), Lemon(E),	Citrus medica
Gritakumari, Aloe, Ghiu-kumar,	Aloe indica
Gulancha, Gurchao (H),	Tinospora cordifolia
Gulmakmal, Gulmakmal (H),	Gomphrena globosa
Halde-hurhuria, Kanphuti-hulhul,	Cleome viscosa
Halshi,	Aegicerus majus
Halud, Turmeric (E), Hardi (H),	Curcuma longa
Harjora, Kharbi (H),	Vitis quadrangularis
Hatichoke, Artichoke, Atipich(H),	Helianthus tuberosus
Hatichur, Hattasura (H),	Heliotropium indicum
Heshnahena, Heshnahena (E),	Cestrum nocturnum
Hidjal, Hidjal (E), Hidjal (H),	Barringtona acutangula
Hijlibadam, Cashew-nnt, Kaju	Anacardium occidentale
Hincha, Harhuch (H),	Enhydra fluctuans
Hing, Hing (H),	Ferula asafoetida
Hogla, Gondri (H), Elephant grass	Typha elephantina
Jaba, China rose (E), Jasoon(H),	Hibiscus Rosa-sinensis
Jam, Blackberry (E), Jamur (H),	Eugenia Jambolena
Jamrul Star Apple (E),	Eugenia malaccensis
Jangli badam, Jangli badam, (H),	Sterculis Fœtida
Jangli matar or Mushur chana,	Lathyrus aphaca
Jarul, Jarul (H),	Lagerstrœmia Flos-regina
Jayphal, Nutmeg (E), Jaiphal(H),	Myristica fragrans
Jeera, Cumin seed (E), Jeera (H)	Cuminum cyminum
Jhau, Tamarisk (E), Jhau (H)	Tamarix gallica
Jhinga, Tarui (H)	Luffa acutangula
Jhumkolata, Passion flower (E)	Passiflora foetida
Jioli, Jingam (H),	Odina Wodier
Job, Barley (E), Jaw (H),	Hordeum vulgare
Joi, Oat (E), Joi (H),	Avena sativa
Joypal, Jamalgota (H),	Croton tiglium

Juan, Ajowan (E), Ajowan (H),	Carum copticum
Jui, Joi (E), Jasmine (H),	Jasminum apsiculatnse
Kachurjpana, Water hyacinth (E),	Eichornia speciosa
Kadamba, Kadam (H),	Anthocephalus Cadamba
Kakrole, Kakrole (H),	Momordica Cochinchinensis
Kalajira, Kalajeera (H),	Nigella sativa
Kalkasunda, Kasunda (H),	Cassia sophera
Kalikaphul, Pilakaner (H),	Thevetia nerifolia
Kalmi, Midnapur creeper, Kalambi	Ipomoe reptans
Kalmeg, China box, Karyal (H),	Andrographis paniculata
Kamini, Marchula (H),	Murraya exotica
Kamlanebu, Orange, Narangi	Citrus aurantium
Kamranga, Chi. gooseberry Kamrak	Averrhoa carambola
Kanchan, Kachnar (H),	Bauhinia acuminata
Kanchira	Commelina benghalensis
Kandapuspa,	Globba bulbifera
Kantagurkamai, Karil (H),	Capparis sepiaria
Kantal, Jack (E), Kantar (H),	Artocarpus integrifolia
Kantalichampa, Kanthalichamp	Artabotrys odoratissima
Kanta nati, Thorny amaranth (E),	Amarantus spinosus
Kantikari, Kateli (H),	Solanum xanthocarpum
Kapas, Cotton (E), Rooi (H),	Gossypium herbaceum
Karabi, Oleander (E), Kaner (H),	Nerium odorum
Karala, Balsam-apple, Karela (H),	Momordica charantia
Karamcha, B. currant, Karanda	Carissa carundas
Katchampa, Gulachin (H),	Plumeria acutifolia
Kathbael, Elephant apple (E),	Feronia Elephantum
Kea, Screwpine (E), Kebra (H),	Pandanus fascicularis
Keshardam,	Jussiaea repens
Keshurta, Mochkand (H),	Eclipta alba
Khair, Catechu (E), Katha (H),	Acacia Catechu
Khejoor, Datepalm (E), Khejoor,	Phoenix sylvestris
Kheshur, Kysoor (H),	Scirpus grossus
Khetpapra, Dhamanpapar (H),	Oldenlandia corymbosa
Khudipana, Duckweed (E),	Lemna polyrrhiza
Kochoo, Kachu (E), Kachalu (H),	Colocasia antiquorum
Kola, Banana (E), Kela (H),	Musa paradisiaca
Kooch, Crab's eye (E), Rati (H),	Abrus precatorius
Kool, Roundplum (E), Bair (H),	Zizyphus jujuba
Krishnachura (E),	Caesalpinia pulcherrima

Krishnakali, 4 O' clock plant (E), Gul-abbas (H),	Mirabilis jalapa
Kukshima, Kunchli (H),	Vernonia cinerea
Kulekhara, Gokshura (H),	Hygrophila spinosa
Kumarika, Chob-chini (H),	Smilax macrophylla
Kumud or shalook,	
Kunda, Maniflower (E), Chameli	Jasminum pubescence
Kurchi, Karchi (H),	Holarrhena antidysenterica
Kush, Dubh (H),	Eragrostis cynosuroides
Kushumphul, Safflower, Kusam,	Carthamus tinctorius
Labanga, Cloves (E), Loang (H),	Eugenia caryophyllata
Lajjabati, S. plant, Lajvanti (H),	Mimosa pudica
Lalbharenda, Jangli erandi, (H),	Jatropha gossypifolia
Lalpata, Chrismas plant (E),	Euphorbia pulcherrima
Lanka, Chili (E), Lalmarich (H),	Capsicum frutescens
Lau, Gourd (E), Kaddu (H),	Lagenaria vulgaris
Lichoo, Lichi (E), Lichoo (H),	Nephelium Litchi
Loquat, Loquat (E), Loquet (H),	Eriobotrys japonica
Madar, Coral (E), Madar (H),	Artocarpus Lakoocha
Madhobilata, Hati mukta (H),	Hiptage Madablota
Madhurkati, Mat straw (E),	Cyperus tegetum
Makhal, Lal indrayan (H),	Trichosanthes palmata
Malati, Malati (H),	Aganosma caryophyllata
Mallika, Chamli (H),	Jasminum sambac
Manjista, Manjit (H),	Rubia Cordifolia
Mankochoo, Mankanda (H),	Alocasia indica
Manshasij, Cactus (E), Sij (H),	Euphorbia nerifolia
Mashkalai, Mash (H),	Phaseolus radiatus
Mashina, Flax (E), Tishi (H),	Linum usitatissimum
Mashur, Lentil (E), Mushuri (H)	Lens esculenta
Mashur chana, Kheshari (H),	Lathyrus aphaca
Matar, Pea (E), Matar (H),	Pisum sativum
Mauri, Anise (E), Sunp (H),	Foeniculum vulgare
Mehadi, Henna (E), Mehadi (H),	Lowsonia alba
Mehagony, Mehagony (E),	Swietenia Mahagoni
Mesta pat, San (H),	Hibiscus cannabinus
Mitha kumra, Gourd, Kumra(H),	Cucurbita maxima
Mooch kunda, Kanak-champa (E),	Pterospermum acerifolium
Moog, Green gram, Mong (H),	Phaseolus aurea
Mootha, Mootha (H),	Cyperus rotundus

Morogphul, Cock's comb, Murga	Celosia argentea
Moyna kanta, Pindu (H),	Vangueria spionsa
Muktojhuri, Khokali (E),	Acalypha indica
Mula, Radish (E), Muli (H),	Raphanus sativus
Nagphani, Nag-phana (H),	Opuntia Dillenii
Narikel, Cocoanut, Nariel (H),	Cocos nucifera
Nashpati, Pear, Nashpati (H),	Pyrus communis
Nata, Katkaranja (H),	Caesalpinia Bonducella
Nayantara, Gul-feringa (H),	Vinca rosea
Naul, Sar (H),	Saccharum arundinaceum
Nebu, Lemon (E), Nemu (H),	Citrus acida
Nebughash, L. grass, Aghiaghas,	Andropogon shoenanthus
Nil, Indigo (E), Nil (H),	Indigotera sumatrana
Nil lata,	Thunbergia grandiflora
Nim, Margosa (E), Nim (H),	Melia Azadirachta
Nishinda, Neergandi (H),	Vitex Negundo
Nole, Chalmeli (H),	Phyllanthus distichus
Nooney shak, Loniya (H),	Portulaca quadrifida
Nona, Crab apple (E), Ramphal	Anona reticulata
Ol, Teliga potato, Jamin-kand,	Amorphophalus campanulata
Ol-kapi, Kohl rabi (E),	Brassica oleracea
Padma, Lotus (E),	Nelumbium speciosa
Palas, Bastard teak(E),Dak (H),	Butea frondosa
Paltemadar, Pangra (H),	Erythrina indica
Pan, Betel (E), Pan (H),	Piper Betle
Paniphal, W. chestnut, Singhara,	Trapa bispinosa
Panmarich,	Polygonum orientale
Panthopadop, Traveller's tree	Ravenala madagascarina
Parul, Parun (H),	Stereospermum suaveolens
Pat, Jut (E), San (H),	Corchorus capsularis
Patal, Parbol (E), (H)	Trichasanthes dioica
Patashaola, Siwar (H),	Vallisneria spiralis
Patharkuchi, Kop-pata (H),	Bryophyllum calycinum
Pati, Mat (E), Chetar (H),	Clinogyne dichotoma
Peach, Peach (E), Aru (H),	Prunus persica
Peepul, Pipal (H),	Ficus religiosa
Penpya, Papita (H),	Carica Papaya
Petari, Jhampi (H),	Abutilon indicum
Peyara, Guava (E), Amrud (H),	Psidium guyava
Phalsa, Falsha (H),	Grewia asiatica

Phanimansha, Nag-phana (H),	Opuntia Dillenii
Phulkopi, Cauliflower, Phulgabi	Brassica oleracea,
Phuti, Phut (H), Melon (E),	Cucumis melo
Pianj, Onion (E), Pianj (H),	Allium cepa
Pipul, Pipli (H); Long pepper (E)	Piper longum
Pituli, Pindara (H),	Trewia nudiflora
Pudina, Mint (E), Pudina (H),	Mentha arvensis
Puin, Poi (H), Basil (E),	Basella rubra
Punarnaba, Gadha-purna (H),	Boerhaavia repens
Radhachura, Gold mohar, (E)	Poinciana regia
Radhuni, Chandani (H),	Carum Roxburghiana
Rajanigandha, Tiger rose,	Polyanthes tuberosa
Ranga alu, S. potato, Mitha alu,	Ipomoea Batatas
Rangan, Raktaka (H),	Ixora coccinea
Rashna, Rashna (H),	Vanda Roxburghii
Rashun, Garlic (E), Rashun (H),	Allium sativum
Rerhi, Castor (E), Arand (H).	Ricinus communis
Ritha, Soap nut (R), Ritha (H),	Sapindus trifoliatus
Rudraksha, Rudraksa (E),	Elaeocarpus Ganitrus
Sajina, Horse radish, Sajina. (H)	Moringa pterygosperma
Sal, Sal (H)	Shorea robusta
Santi, Sunt, Indian arrowroot,	Curcuma zeodoria
Sarbojoya, Indian shot (E),	Canna indica
Samudrashok, Chhota bistarak	Argyreia speciosa
Sarisha, Mustard (E), Karua (H),	Brassica Napus
Satamuli, Shrikakul (H),	Asparagus racemosus
Sada hurhurhe, Charota (H),	Gynandropsis pentaphylla
Shalgom, Turnip (E), Salgom (H),	Brassica campestris
Shalook, Waterlily(E), Kamal	Nymphaea lotus-stellata
Shankaloo, Sankerkand (H),	Pacyrhizus angulatus
Shasha, Cucumber, Khira (H),	Cucumis sativus
Sheuli, Night-jasmine, Harsingar,	Nyctanthes Arbortristis
Sheal kanta, Yellow-thistle (E),	Argemome mexicana
Sheakul,	Zizyphus oenoplia
Shibjhul, Naphat (H),	Cardiospermum Halicacaba
Shegoon, Teak (E), Shegun (H),	Tectona grandis
Shij, Shij (H),	Euphorbia Nivulia
Shim, Bean (E), Shim (H),	Dolichos Lablab
Shimul, Silk Cotton, Shalmali(H),	Bombax malabaricum
Shola, Sola (E), Kag (H),	Aeschynomene aspera

Shishu, Shisam, (H),	Dalbergia Sishoo
Shoregonja, Ram-til, (H),	Guizotia abyssinica
Shukhadarsan, Chindar (H),	Crinum latifolium
Shulpa, Ban-shulpa (H),	Pencedanum graveolens
Shushnishak,	Marsilia
Shingara, W. chestnut, Singara,	Trapa bispinosa
Shiris, Rain tree (E), Shiris (H),	Albizzia Lebbek
Sthalpadma, Changeable rose (E),	Hibiscus mutabilis
Sundri,	Heritiera minor
Supari, Betel nut (E), Shupari,	Areca catechu
Surjamukhi, Sun flower (E),	Helianthus annuus
Swarnalata, Dodder (E),	Cuscuta reflexa
Swet Chandan, Sandal wood,	Santalum album
Tagar, Taggar (H),	Tabernaemontana coronaria
Tal, Fan-palm (E), Tar (H),	Borassus flabellifer
Tamak, Tobacco, Tamaku (H),	Nicotiana Tabacum
Tapari, Cape gooseberry, Tepari,	Physalis peruviana
Tarmuz, Melon (E), Tarbuz (H),	Citrullus vulgaris
Tarulata, Kam-lata, (H),	Quamoclit pinnata
Tejpat, Cassia-leaf, Tejpotra (H),	Cinamomum Tamala
Telakucha, Bhimb (H),	Cephalandra indica
Tentul, Tamarind, Imli (H),	Tamarindus indica
Teshiramansha, Tindharasij (H),	Euphorbia antiquorum
Thankuni, White rot, Mudaki	Hydrocotyle asiatica
Tishi, Linseed, Alsi (H),	Linum usitatissimum
Topemari, Sabzah (H),	Salvia aegyptica, varpumila
Topapana (see Barapana)	Pistia stratiotes
Tulshi, Holy Basit, Tulshi,	Ocimum sanctum
Tunt, Mulberry, Tutri (A),	Morus indica
Uchhe, Karela (H),	Momordica charantia
Uk, Sugar cane (E), Ganna (H),	Saccharum officinarum
Ulat kambal, Olat kambol (H),	Abroma augusta
Ulat chandal, Languli (H),	Gloriosa superba
Ulughas, Dubh (H),	Imperata arundinacea
Ush-shaora, Ban-nimbu, (H),	Glycosmis pentaphylla.

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